BULLETIN

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Operations Research Society of America

1964–1965

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BULLETIN

OF THE

Operations Research Society of America

Supplement 1 OPERATIONS RESEARCH Volume 13, 1965

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II

The Boston, Massachusetts Meeting

Twenty-seventh National Meeting

PROGRAM THEME

"New Directions in Operations Research"

The 27th National Meeting of the Operations Research Society of America, to be held at the Statler Hilton Hotel in Boston, Massachusetts, Thursday and Friday, May 6–7, 1965, will have as its theme *New Directions in Operations Research.* The field of Operations Research was a product of the wartime efforts of technical people working under the pressure of military urgency to produce solutions to operational problems faced by combat forces. The end of the war permitted Operations Research scientists to take a longer, more detailed look at the problems they were studying, to develop new tools for the solution of these problems and to consult the specialists in fields other than their own for additional insights into their problems.

The decade following the end of World War II saw a great increase in the field of Operations Research. Its applications to fields other than military were numerous; many textbooks were written describing the field and its methods; it became a part of the curricula of many recognized technical schools and universities; its practitioners formed professional societies. Many of its wartime triumphs were matched by successes in the industrial field and it had, by the middle fifties, become a well-established and recognized part of American technology.

It is characteristic of Operations Research that it continue to seek new areas of application. The second post-war decade has seen further expansion of the field into such areas as transportation, law and medicine; economic, social and political questions have become as much a part of the diet of the Operations Analyst as military questions had formerly been. Equipped with new tools and techniques and a new generation of people trained in its methods, Operations Research appears to be well-prepared to make its contribution to an advancing American society along a very broad front. The program of the 27th National Meeting has been organized to provide a sampling of the new techniques and applications of Operations Research.

REGISTRATION INFORMATION

Registration

The registration desk will be located on the Mezzanine of the Statler Hilton Hotel and will be open:

Wednesday, May 5	6:00 p.m.–9:00 p.m
Thursday, May 6	8:00 a.m.–5:00 p.m.
Friday, May 7	8:00 a.m.–4:00 p.m.

Fees for registration and events are:

Members	$10.00
Non-Members	$12.00
Students	$3.00
Luncheons	$4.00 (each)
Banquet	$7.00

An ORSA Meeting Office will be set up at the Statler Hilton and will serve as a message center for those attending the meeting. There will be *no advance registration* for this meeting.

Accommodations

The Statler Hilton Hotel has reserved a block of rooms for meeting attendees. All meetings and functions will be held in the Hotel. The Hotel is located at Park Square in downtown Boston, a fifteen minute ride from Logan Airport, the international terminal serving Boston. Limousine service is available between the airport and the Hotel for $1.25. Taxi fare is about $3.00. Rail connections can be made through North or South Stations in Boston, both located near the center of town.

A reservation card is enclosed and should be sent directly to the Hotel.

Employment Notices

The Society does not operate a clearing house for recruiting activities. However, a bulletin board for the display of employment notices and other recruiting information will be provided at the meeting. Such notices must be in the standard format of 8½″ x 11″ and should be sent to DR. EDWARD A. SILVER, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts, 02140, for posting.*

Copies of Papers Presented at Meeting

Requests for copies of papers should be made directly to the authors, at the addresses given with the abstracts. Neither the Meeting or Program Chairmen, the BULLETIN Editor nor others in ORSA have copies for distribution.

The New Boston!

Many ORSA members are no doubt well-acquainted with historic Boston, but there will be many surprises for those who have not been to "The Hub" for several years. The Prudential Center in Back Bay, with its 52 story tower and new auditorium will be nearly finished in May. Colorful but decrepit old Scollay Square has become the impressive Government Center. Nearly every block in the city has been caught up in the progressive theme of "The New Boston." Even the familiar MTA has surmounted suboptimization and become the Massachusetts Bay Transportation Authority.

The month of May is delightful in Boston and environs. Boston's many theaters are still open, with usually an excellent selection of pre- and post-Broadway shows. Moreover, it's the month of the Boston Pops at Symphony Hall.

The Statler Hilton Hotel is literally in the midst of the famous walking tour, the Freedom Trail. Many rooms overlook the State House, Boston Common, Public Gardens, the swan boats, and almost history itself.

At the hotel desk you'll find an excellent free guide magazine called *Panorama*, which lists current theater, concerts, museum shows, and sports events. It describes major points of interest and the better restaurants and night spots—with a handy reference map. The Gray Lines (at Copley Square) run frequent bus tours of the area's many tourist attractions. The New York World's Fair is an hour away by air shuttle.

Your committee will post notices of other local features to help make your trip to Boston rewarding in many ways.

MEETING COMMITTEE

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D.3 Peter B. Wilson
D.4 Gershon Cooper
D.5 Richard Meyers
D.6 Gordon Shellard

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SYNOPSIS OF MEETING

STATLER HILTON HOTEL, BOSTON, MASSACHUSETTS, MAY 6–7, 1965

Location	Thursday, May 6	Friday, May 7
Mezzanine Registration	8:00 a.m.–5:00 p.m.	8:00 a.m.–4:00 p.m.
Morning Sessions 9:00 a.m.–12:00 noon	**SESSION A**	**SESSION C**
Georgian Room	1. Modern Statistical Decision Theory (Panel)	1. The Structure of Investment Decisions
Stanbro Hall	2. Transportation Systems	2. Stochastic Models in Marketing
Parlor A	3. OR in Real-Time Computer Systems	3. OR on Social Problems
Ballroom West	4. Probabilistic Models	4. Programming Methods of OR
Parlor B	5. Design of Information and Control Systems	5. Theory of Conflict
Ballroom East	————	6. Transportation Science Section of ORSA
Luncheon 12:15–1:45 p.m. Speaker *Ballroom East*	MARSHALL K. WOOD, National Planning Assoc.	KENNETH BOULDING, University of Mich.
Afternoon Sessions 2:00–5:00 p.m.	**SESSION B**	**SESSION D**
Georgian Room	1. Systems Engineering or Operations Research (Panel)	1. Practical Theories of Inventory Control
Stanbro Hall	2. Design of Command and Control Systems	2. Panel on Experimentation in OR
Parlor A	3. Earth Science Applications	3. Transportation and Distribution
Ballroom West	4. Methods & Applications of Decision Theory	4. Quantitative Bases for Investment Decisions
Parlor B	5. Problems & Methods of Marketing	5. Selected Topics in OR
Ballroom East	6. Problems & Techniques of Inventory Control	6. OR in the Insurance Industry (Panel)
Evening Wednesday May 5 Registration 6:00–9:00 p.m.	5:30–7:00 p.m. Mixer (Ballroom West) 7:30 p.m. Banquet (Ballroom East) GEORGE E. KIMBALL, Retiring Presidential Address	

PROGRAM

of the

Twenty-seventh National Meeting

of the

OPERATIONS RESEARCH SOCIETY OF AMERICA

THURSDAY MORNING, MAY 6, 1965 **SESSION A**

(9:00–12:00)

A.1. Modern Statistical Decision Theory, (*A Panel*)

Location: GEORGIAN ROOM

Chairman: RONALD A. HOWARD, *Institute in Engineering Economic Systems, Stanford University, Stanford, California.*

A1a. Position Paper, HERMAN CHERNOFF, *Department of Statistics, Stanford University, Stanford, California.*

A1b. Decision Theory as the Central Stem in an Engineering Curriculum, MRYON TRIBUS, *Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire.*

A1c. The Problem of Applying Modern Decision Methods to Business Situations, DOLPH G. EBELING, *General Electric Company, Schenectady, New York.*

A.2. Transportation Systems

Location: STANBRO HALL

Chairman: MARTIN WOHL, *Economics Department, Littauer House, Harvard University, Cambridge, Mass.*

A2a. A More Systematic Approach to Federal Transportation Policy, JOHN B. MEYER, *Harvard University, Cambridge, Massachusetts.*

A2b. Systems Analysis and the Future of the Railroad Industry. A. S. LANG, *New York Central System, New York, New York.*

A2c. The Role of Systems Analysis in the Highway Transportation Industry, FRANK QUACKENBOSS, *Operations Research Department, Research Laboratories, General Motors Corporation, Warren, Michigan*

A.3. OR in Real-Time Computer Systems

Location: PARLOR A

Chairman: MARTIN L. ERNST, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

A3a. A Criterion for Efficient Computer Storage Allocation in Real Time Systems, R. E. HEITMAN, *A. D. Little, Inc., Cambridge, Massachusetts,* and

A3b. (Continuation), M. N. PERRY, *American Airlines, Albany Post Road, Briarcliff Manor, New York.*

A3c. The Real Problems of Real Time Computing, A. G. OETTINGER, *Harvard University, Cambridge, Massachusetts.*

A3d. Priority Scheduling of Time-Shared Computer Systems, MARTIN GREENBERGER, *Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A.4. Contributed Papers on Probabilistic Models

Location: BALLROOM WEST

Chairman: JAMES M. DOBBIE, *Arthur D. Little, Inc., Cambridge, Massachusetts*

A4a. A Climate for Real Time, FREDERICK J. BURKE, *Spector Freight System, Inc., 205 West Wacker Drive, Chicago, Illinois.*

A4b. On the Concept of FIFOV in Queues, B. KRISHNAMOORTHI, *Stanford University, Stanford, California.*

A4c. Optimum Communications Center Buffer Design, INTS DELGALVIS and RICHARD C. SOUCY, *I.B.M., Kingston, New York.*

A4d. Queueing Analysis of Real-time Computer Systems, WEI CHANG and DONALD J. WONG, *I.B.M., Kingston, New York.*

A4e. The Application of Queueing Theory to the Design of Real-time Computer Systems, EDWARD W. VEITCH and WALTER A. LEVY, *Pennsylvania Research Associates, Inc., 27 South 36th Street, Philadelphia, Pa., 19104.*

A4f. **The Control of Multiple-Channel Queueing Systems with Mixed Input Streams,** JOHN P. YOUNG, *The Johns Hopkins University, Baltimore, Maryland.*

A4g. **A Simulation Approach to Evaluating the Effects of Redirecting Heteromorphic, Variable Delay, Queue Feedback in Multi-Channel, Parallel Systems,** RONALD LESSING and JOHN H. MOSS, *Social Security Administration, Department of Health, Education and Welfare, Washington, D. C.*

A4h. **Sensitivity Analysis of 473L Performance,** STANLEY B. ROSEN and ESSIE S. NEVANS, *General Electric Company, Information Systems Operation, 4901 Fairmont Avenue, Bethesda, Maryland.*

A4i. **An Operational Readiness Model for an Inertial Navigation System,** J. J. MALTESE, *Autonetics, 3370 Miraloma Ave., Anaheim, California, 92803,* and R. A. NELSON, *Vitro Laboratories, Silver Spring, Maryland.*

A4j. **Operations Research Study in a Telephone Company Business Office,** JOHN M. HOLMES, JR., *The Chesapeake and Potomac Telephone Company of West Virginia, 1500 MacCorkle Ave., Charleston, West Virginia.*

A4k. **Analysis and Projection of the Historic Pattern of Supply of Exhaustible Natural Resources.** C. L. MOORE, *Box 582, Benjamin Franklin Station, Washington 44, D. C.*

A.5. Contributed Papers on Design of Information and Control Systems

Location: PARLOR B

Chairman: KENNETH W. YARNOLD, *Dunlap & Associates, Darien, Connecticut*

A5a. **Establishing Objectives, Measures, and Criteria for Multi-Phase Complementary Activities,** SIDNEY I. FIRSTMAN and DAVID S. STOLLER, *The RAND Corporation, 1700 Main Street, Santa Monica, California.*

A5b. **Requirements Analysis and Its Impact on Command System Design,** JOHN A. EVANS, *Information Sciences Department, The MITRE Corporation, Bedford, Massachusetts.*

A5c. **System Reliability in an Electric Utility,** BURTON V. DEAN, *Case Institute of Technology, Cleveland, Ohio, 44106.*

A5d. **Exercising the Modern Command System,** W. H. Tetley, *Cornell Aeronautical Laboratory, Inc., Buffalo, New York, 14221.*

A5e. **Determining a Measure of Effectiveness for a Command and Control System,** J. E. Gernogross and F. J. Huddleston, *Command and Control Department, Defense Systems Division, The Bunker-Ramo Corporation, 8433 Fallbrook Ave., Canoga Park, California, 91304.*

A5f. **The Design of Command and Control Systems for Task Groups,** Lawrence E. Schlesinger, *George Washington University, Washington 6, D. C.*

A5g. **Operations Research as a Money-making Management Tool in Small Production Runs of Electronic Equipment,** James A. Birdwell.

A5h. **Evaluation of Alternate File Structures for Command and Control Systems.** Stanley B. Rosen and Essie S. Nevans, *General Electric Company, Information Systems Operation, 4901 Fairmont Ave., Bethesda, Maryland.*

A5i. **Project Cost Curve—Equivalent Linear Graphs,** V. K. Handa, *Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada.*

A5j. **Testing for Error Contributions in Certain Man-Machine Control Systems,** Stanley P. E. Price, *Federal Aviation Agency, N AFRC RD-713, Atlantic City, New Jersey.*

A5k. **On the Use of Discriminant Analysis for Establishing Decision Rules,** J. Zelnick.

THURSDAY NOON, MAY 6, 1965

(12:15–1:45)

Luncheon

Location: Ballroom East
Speaker: Marshall K. Wood, *Director, Economic Programming Center, National Planning Association*

Subject: **Quantitative Approaches to Public Policy Formation**

THURSDAY AFTERNOON, MAY 6, 1965 SESSION B

(2:00–5:00)

B.1. Systems Engineering or Operations Research, A Panel

Location: GEORGIAN ROOM

Chairman: WILLIAM K. LINVILL, *Stanford University, Stanford, California.*

B1a. Systems—Profession Born of Technological Advance, WILLIAM K. LINVILL, *Stanford University, Stanford, California.*

B1b. Position Paper, R. L. ACKOFF, *University of Pennsylvania, Philadelphia, Pennsylvania.*

B1c. A Systems Engineer Looks at Operations Research, ROBERT E. MACHOL, *Systems Engineering Department, University of Illinois, Chicago, Illinois.*

B1d. Position Paper, ARTHUR D. HALL, *Television Engineering Department, Bell Telephone Laboratories, Murray Hill, New Jersey.*

B.2. Design of Command and Control Systems

Location: STANBRO HALL

Chairman: JOSEPH H. LEWIS, *Institute for Defense Analyses, Weapons Systems Evaluation Division, The Pentagon, Washington 25, D. C.*

B2a. Requirements—The Illusive Elements in System Design, JOEL N. BLOOM, *Industrial Engineering Laboratory, The Franklin Institute, Philadelphia 3, Pennsylvania.*

B2b. Application of Information Flow Studies to Development of Command Support Systems, ROBERT H. ADAMS, *Institute for Defense Analyses, Weapons Systems Evaluation Group, Pentagon, Washington, D. C.*

B2c. An Approach to the Design of Command and Control Systems, W. F. BENNETT, *Washington Systems Center, I.B.M., Bethesda, Maryland.*

B2d. Technical and Monetary Management of the Development of Command Support Systems—A Continuous Activity—The Relationship of Funding Procedures to Development Problems, ROBERT H. SCHERER, *Asst. Deputy Director of Defense Research and Engineering NMCS (TS) and Strategic Command and Control, Department of Defense, Washington, D. C.*

B.3. Earth Science Applications of Operations Research

Location: PARLOR A

Chairman: DOUGLAS L. BROOKS, *The Travelers Research Center, Inc., Hartford, Connecticut.*

B3a. **The Exploitation of Geophysical Information in Naval Operations,** GEORGE H. MILLY and JOSEPH G. BRYAN, *The Travelers Research Center, Inc., Hartford, Connecticut.*

B3b. **The Difference Between Weather Forecasters and Weather Advisors,** R. R. RAPP, *The RAND Corp., Santa Monica, Calif.*

B3c. **The Synthesis and Use of Long Hydrologic Records in Resource Planning,** MYRON B. FIERING, *Harvard University, Cambridge, Massachusetts.*

B3d. **Resource Planning in Ocean Surveys,** HAROLD NISSELSON, *Operations Research Incorporated.*

B.4. Contributed Papers on Methods and Applications of Decision Theory

Location: BALLROOM WEST

Chairman: GORDON M. KAUFMAN, *School of Industrial Management, Massachusetts Institute of Technology, Cambridge, Mass.*

B4a. **Reliability Statements Under Uncertainty,** WARREN G. BRIGGS, *Harbridge House, Inc., 11 Arlington Street, Boston, Massachusetts.*

B4b. **Optimum Policy Regions for Markov Processes with Discounting,** RICHARD D. SMALLWOOD, *The Institute in Engineering-Economic Systems, Stanford University, Stanford, California.*

B4c. **A Decision-Theoretic Evaluation of an Idealized Bomb-Damage Assessment Information System,** UGO O. GAGLIARDI, *Dunlap and Associates, Darien, Connecticut.*

B4d. **Hypothesis Testing in Command and Control,** H. GUMBEL, *Lockheed Missiles and Space Co., Sunnyvale, Calif.*

B4e. **The Constant Likelihood of the Residual Hypothesis in Bayesian Statistics,** RAYMOND H. BURROS, *System Development Corporation, 45 Hartwell Ave., Lexington, Massachusetts*

B4f. **Methods of Measuring Utilities Under Independence,** PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia.*

B4g. On the Expected Gain of a Markov Chain with Uncertain Transition Probabilities. J. J. Martin, *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.*

B4h. Hierarchically-Structured Sequential Decision Processes: A Bayesian Decision Theory Model, Marvin L. Manheim, *Directorate of Transportation, Office of the Deputy Chief of Staff/Logistics, Headquarters U. S. Army, Nassif Building, Washington, D. C., 20315.*

B4i. Relevance of Statistical Decision Theory to Fault Isolation, Richard J. Matteis, *Dunlap and Associates, Inc., Darien, Connecticut.*

B4j. Optimum Bayes Strategies in Truncated Life Testing, Robert J. Martel, *Technical Operations Inc., South Avenue, Burlington, Massachusetts.*

B4k. Generation and Simulation of Attributes Sampling Plans with a Detailed Analysis of Wald's Sequential Probability Ratio Plans with Truncation, Hal Nissley, *I.B.M., 2925 Euclid Avenue, Cleveland, Ohio, 44115.*

B4l. An Experiment with a Methodology for System Comparison and Selection, P. R. Fatianow, *General Electric/ASD, Daytona Beach, Florida.*

B.5. Contributed Papers on Problems and Methods of Marketing

Location: Parlor B

Chairman: Charles K. Ramond, *Advertising Research Foundation, New York, New York*

B5a. Monte Carlo Analysis of Consumer Behavior in Product Tests, Ralph L. Day, *The Pennsylvania State University, University Park, Pennsylvania, 16802.*

B5b. Introduction of a New Brand in a Highly Competitive Consumer Product Market: Problems, Measurement of the Impact, and Testing of the Managerial Hypothesis, Yoshiro Kuratani, *Case Institute of Technology, Cleveland 6, Ohio.*

B5c. **Improving the Accuracy of Market Share Prediction Under Conditions of Innovation: Practical and Theoretical Considerations in the Application of a Modified Markovian Model,** Rafael B. Cruz, *Merle Thomas Corporation, Houston, Texas, 77036* and J. O. Eastlack, Jr., *Bristol Myers Company, New York, New York.*

B5d. **A Dynamic Model for Competitive Marketing in Coupled Markets,** Melvin F. Shakun, *Rutgers—The State University, New Brunswick, New Jersey.*

B5e. **A Biometric Model of Advertising.** Federico Frischknecht, *University of Buenos Aires, Buenos Aires, Argentina.*

B5f. **An Operational Theory for Marketing Differentiated Products,** Robert C. Hain, *Corning Works, Corning, New York,* and S. S. Sengupta, *University of Pennsylvania, Philadelphia, Pennsylvania.*

B5g. **Effect of Company Objectives and Marketing Environment on Optimum Proposal Expenditures for a Government Contractor,** Everett J. Daniels, *Lockheed-California Company, Burbank, California.*

B5h. **Imperfect Monitoring of a Markov Source with Associated Costs,** Alvin W. Drake, *Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.*

B5i. **Improving Advertising Quality—An Analytical Approach,** Irwin Gross, *Scott Paper Company, Philadelphia, Pennsylvania, 19113.*

B5j. **Variance Considerations Research Design,** Eli S. Marks, *Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania.*

B.6. Contributed Papers on Problems and Techniques of Inventory Control

Location: Ballroom East

Chairman: Edward H. Bowman, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

B6a. **An Approximate Solution for a Multi-echelon Inventory System,** R. L. Layton, *Bell Telephone Laboratories, Holmdel, New Jersey.*

B6b. Decision Aid for Spare Parts Provisioning, L. R. GUTSTADT, *North American Aviation, Space and Information Systems Division, 12214 Lakewood Blvd., Downey, California.*

B6c. Bayesian Determination of the Reorder Point of a Slow Moving Item, EDWARD A. SILVER, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge 40, Massachusetts.*

B6d. Practical Aspects of Economic Order Quantities, IRVING KATZ, *Operations Analysis Office, HQ Air Force Logistics Command, Dayton, Ohio.*

B6e. Improved Control of an Operating Distribution System, JAMES P. MORRIS and ROBERT CLEVELAND, *Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland,* and JOSEPH GLASER, *American Airlines, New York, New York.*

B6f. An Allowance List Decision Rule on METRI, BERNARD N. SAMERS, *Clark, Cooper, Field & Wohl, Inc., 123 High Ridge Road, Stanford, Connecticut.*

B6g. A System for Evaluating Purchase Strategies in Resale Industries, JAMES H. HEEREMANS, *Arthur Anderson & Co., 294 Washington St., Boston 8, Massachusetts.*

B6h. A New Approach to Inventory Stockout Penalty Costs. BENJAMIN L. SCHWARTZ, *Data Dynamics, Inc., 305 Webster St., Monterey, California.*

B6i. The Weibull Distribution as an Inventory Control Application, JOSEPH W. TIMPE and JAGDISH N. PATEL, *Microswitch Division of Honeywell, Inc., Chicago and Spring Streets, Freeport, Illinois.*

B6j. Optimal Procurement Decisions for Spare Aircraft Components, D. HOEKSTRA, R. L. DEEMER, and S. GADJALO, *Frankford Arsenal, Building 109-3, Bridge and Tacony Streets, Philadelphia, Pennsylvania.*

THURSDAY EVENING MAY 6, 1965

(5:30–7:00)

Cocktail Hour & Mixer

Location: BALLROOM WEST

(7:30)

Banquet

Location: BALLROOM EAST

Retiring Presidential Address

GEORGE E. KIMBALL, *Vice President, Arthur D. Little, Inc.*
Introduced by
PHILIP M. MORSE, *Massachusetts Institute of Technology*

FRIDAY MORNING, MAY 7, 1965

(9:00–12:00)

C.1. The Structure of Investment Decisions

Location: GEORGIAN ROOM

Chairman: GEORGE R. MURRAY, *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

C1a. Practical Difficulties in Attacking the Investment Problem, HERBERT AYRES, *Morgan Guarantee Trust Company, New York, New York.*

C1b. Mathematical Models in Capital Budgeting: Opportunities and Limitations, CHARLES CHRISTENSON, *Harvard Business School, Soldiers Field Road, Boston, Massachusetts.*

C1c. The Effect of Accounting Conventions on Business Investment Standards, JOHN F. MAGEE, *Vice President, Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

C1d. The Nature of Risk in Investment Decisions, DAVID B. HERTZ, *McKinsey & Company, New York, NewYork.*

C1e. **Problem Areas in Securities Analysis and Portfolio Management,** L. G. PECK, *Goldman, Sachs and Co., 20 Broad Street, New York 5, New York.*

C.2. Stochastic Models in Marketing

Location: STANBRO HALL

Chairman: LAWRENCE FRIEDMAN, *Operations Research Director, M and M Candies, Hackettstown, New Jersey.*

C2a. **The Use of Stochastic Market Models in the Analysis of Consumer Panel Data,** JEROME D. HERNITER, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

C2b. **New Product Introduction—A Perturbation in the Market Place,** BENJAMIN LIPSTEIN, *Benton & Bowles, Inc., New York, New York.*

C2c. **A Model of Adaptive Control of Promotional Spending,** JOHN D. C. LITTLE, *Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

C2d. **Order and Homogeneity of Family-Specific Markov Chains for Coffee Brand Choice,** WILLIAM F. MASSY, *Graduate School of Business, Stanford University, Stanford, California.*

C2e. **New Dimensional Analysis of Brand Switching,** ALFRED KUEHN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania,* and ALBERT C. ROHLOFF, *Lever Brothers Company, New York, New York.*

C.3. Contributed Papers on OR on Social Problems

Location: PARLOR A

Chairman: HARRY ELLIS, *Harbridge House, Boston, Massachusetts.*

C3a. **Optimal Procedure for An N-State Testing and Learning Process,** W. KARUSH and R. E. DEAR, *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California, 90406.*

C3b. **Heuristic Games for Secondary Schools.** CLARK C. ABT, *Abt Associates, 24 Concord Lane, Cambridge, Massachusetts.*

C3c. A Model for the Design of Prepaid Dental Plans, DAVID A. SCHRADY and BURTON V. DEAN, *Case Institute of Technology, Cleveland, Ohio, 44106.*

C3d. Operations Research and the Study of Public Policy Problems: A Specific Case, ERIK A. R. HALDANE, *Department of Economic Affairs, Organization of American States, Pan American Union, 1725 "I" Street, N.W., Room 1009, Washington, D. C., 20006.*

C3e. Investment Decisions in Newly Developing Countries, MORRIS J. SOLOMON, *U. S. Bureau of the Census, Washington 25, D. C.*

C3f. Operations Research: Can it Implement, or Create, Social Values?, SAMUEL E. GLUCK, *Division of Business, Hofstra University, Hampstead, L. I., New York.*

C3g. Predicting Air Pollution Levels, RONALD W. WOLFF, *Department of Industrial Engineering, University of California, Berkeley, California.*

C3h. Game Theory Applications to Service Site Selection, WILLIAM L. MOOG and NEWTON DIKOFF, *Social Security Administration, Department of Health, Education and Welfare, Washington, D. C.*

C3i. A Model for the Prediction of Demand for Nursing Service, WARREN H. THOMAS, *Department of Industrial Engineering, State University of New York at Buffalo, Buffalo, New York.*

C3j. The Library as an Inventory Problem, RICHARD W. TRUESWELL, *School of Engineering, University of Massachusetts, Amherst, Massachusetts.*

C.4. Contributed Papers on Programming Methods of Operations Research

Location: BALLROOM WEST

Chairman: DAVID F. VOTAW, JR., *The MITRE Corporation, Bedford, Massachusetts.*

C4a. Modular Design, Generalized Inverses and Convex Programming, A. CHARNES, *Northwestern University, Evanston, Illinois,* and M. KIRBY, *Research Analysis Corporation.*

C4b. Techniques for Solving Multiple Assignment Problems, HARVEY WOLFE, *Department of Industrial Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania.*

C4c. A Resource Allocation Problem, SOCRATES LITSIOS, *Booz, Allen Applied Research, Inc., 4815 Rugby Ave., Bethesda, Maryland.*

C4d. Decomposition Analysis for Multiple Constraint Values and Objective Functions, JOHN S. BONNER, *Bonner and Moore Associates, Inc., Houston, Texas,* JOHN P. BASILE, and HARRY GILDEA, *Management Systems Corporation, Cambridge, Massachusetts.*

C4e. A Defense System Budget Allocation Study, (*See Authors, C4d.*)

C4f. The Chinese Postman's Problem, JACK EDMONDS, *National Bureau of Standards, Washington, D. C., 20234.*

C4g. Primal-Dual Decomposition Programming, EARL J. BELL, *Department of Industrial Administration, The University of Connecticut, Storrs, Connecticut.*

C4h. The NORMA: A Possible Basis for a Theory for the Traveling-Salesman Problem, NORMAN P. SALZ, *Cornell Aeronautical Laboratory, Inc.*

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C.5. Theory of Conflict

Location: Parlor B

Chairman: Peter Cole, *Institute for Naval Studies, Cambridge, Massachusetts.*

C5a. The Distribution of the Time-Duration of Stochastic Duels, C. J. Ancker, Jr., and A. V. Gafarian, *System Development Corporation, Santa Monica, California.*

C5b. On Developing Models of Conflict, Roger L. Sisson, *University of Pennsylvania, Philadelphia, Pennsylvania.*

C5c. An Inductive Theory of Dynamic Combat, Seth Bonder, *Systems Research Group, Department of Industrial Engineering, The Ohio State University, 156 W. 19th Avenue, Columbus, Ohio. 43210.*

C5d. Operational Problems in Static and Dynamic Calibration of a Newly Developed Scoring Device for Aerial Targets, Roger W. Winslow. *Stanford Research Institute, P.O. Box 316, Fort Ord, California.*

C5e. Field Experimentation in Operations Research, Frank J. Harris, *Stanford Research Institute, Research Office, U. S. Army Combat Developments Command Experimentation Center, P.O. Box 316, Fort Ord, California.*

C5f. Low Altitude Penetration Parametric Study, P. T. Chan, C. W. West, and F. M. Weinberger, *Vought Aeronautics Division, Ling-Temco-Vought, Inc., Dallas, Texas.*

C5g. A Model for Allocating Defense Resources, Peter D. Fox and Iram J. Weinstein, *Stanford Research Institute, Menlo Park, California.*

C.6. Meeting of the Transportation Science Section

Location: Ballroom East

Chairman: Robert S. Foote, *Port of New York Authority, New York, New York 10011.*

C6a. Statistical Study of Factors Influencing Safety at Highway-Rail Grade Crossings, Leon Wester, *I.I.T. Research Institute, Chicago, Illinois,* and Gerald M. Magee, *Association of American Railroads.*

C6b. Computer Simulation of Peak-Hour Passenger Movements on the PATH (Port Authority Trans-Hudson) System, James J Browne, *The Port of New York Authority, New York, New York 10011.*

C6c. A Time-Dependent Queueing Model and Application to Airport Delays, K. G. Grossman, R. C. Wheeler, *Airborne Instrument Laboratory, Deer Park, Long Island, New York 11729.*

C6d. Fast Time Simulation of a High Performance Terminal Area Traffic Control System, R. W. Simpson, *Assistant Professor, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

C6e. Optimum Control of an Unsaturated Artery, J. Johnson, *IBM Data Processing Division, Yorktown Heights, New York*

FRIDAY NOON, MAY 7, 1965

(12:15–1:45)

Luncheon

Location: Ballroom East

Speaker: Kenneth E. Boulding, *Professor of Economics, University of Michigan.*

Subject: **The Ethical Implications of Rational Decision**

FRIDAY AFTERNOON, MAY 7, 1965 SESSION D

(2:00–5:00)

D.1. Practical Theory of Inventory Control

Location: Georgian Room

Chairman: Jerome D. Herniter, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

D1a. Aggregate Inventory Management, Robert G. Brown, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

D1b. Product Line Evolution in the Retail Store, GEORGE R. MURRAY, JR., *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

D1c. Applied Inventory Models, T. M. WHITIN, *Wesleyan University, Middletown, Connecticut.*

D1d. An Empirical Study of Exactly and Approximately Optimal Inventory Policies, HARVEY M. WAGNER, *Stanford University.*

D.2. Experimentation In Operations Research, A Panel

Location: STANBRO HALL

Chairman: HUGH J. MISER, *The MITRE Corporation, Bedford, Massachusetts.*

D2a. Observation and Experimentation in Operations Research.
Panelists: EDWARD H. BOWMAN, *Massachusetts Institute of Technology,*
ROBERT S. FOOTE, *The Port of New York Authority,* and
GEORGE R. LINDSEY, *Defence Research Board of Canada.*

D.3. Contributed Papers on Transportation and Distribution

Location: PARLOR A

Chairman: PETER B. WILSON, *Canadian National Railways, Montreal, Quebec, Canada.*

D3a. Most Profitable Routing Before Maintenance, CHRISTOPH WITZGALL and A. J. GOLDMAN, *National Bureau of Standards, Washington, D. C. 20234*

D3b. An Airport Capacity Handbook: Results of a Federal Aviation Research Program in Mathematical Models and Techniques for Determining Airport Capacity, OSCAR SHAPIRO, *Federal Aviation Agency, Research Division, Atlantic City, New Jersey.*

D3c. A Study of Car-Pool Systems in Railroad Transportation, B. AVI-ITZHAK, BENJAMIN A. BENN, and BRUCE A. POWELL, *Case Institute of Technology, Cleveland 6, Ohio.*

D3d. An Operational Solution of a Large Scale Delivery Problem, RALPH BOEKEMEIER, *Continental Copper & Steel Industries, Inc., 100 East 42nd Street, New York, New York 10017.*

D3e. Aerospace Systems Approach Applied to Regional Transportation Planning, JOHN H. TINLEY, and SIDNEY MOGLEWER, *Douglas Aircraft Company, Inc., 3855 Lakewood Blve., Long Beach, California*

D3f. Optimal Route Assignment for Metropolitan Road Traffic. ALAN HERSHDORFER, *Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

D3g. A Study of a Motor Bus Undertaking, J. G. CROOKES, *British European Airways, London Airport, England,* K. B. HALEY, *The University, Edgbaston, Birmingham 15, England,* and P. J. PENGILLY, *Proctor & Gamble Limited, Newcastle Upon Tyne 3, England.*

D3h. Necessary and Sufficient Conditions for a Solution to the Multifacility Production-Transportation Problem with Nonlinear Production Costs, J. FRANK SHARP and H. R. PRASAD, *Industrial Engineering Department, Rutgers—The State University, New Brunswick, New Jersey.*

D3i. A Computer Program for Automatic Planning of Logistic Airlifts, HANS J. BERLINER, *Washington Systems Center, I.B.M., Bethesda, Maryland.*

D.4. Contributed Papers on Quantitative Bases for Investment Decisions

Location: BALLROOM WEST

Chairman: GERSHON COOPER, *Dunlap & Associates, Darien, Connecticut.*

D4a. Risk Measurement in Capital-Investment Decision-Making, NORMAN N. BARISH and SEYMOUR KALAN, *Department of Industrial Engineering and Operations Research, New York University, New York, New York 10435.*

D4b. Expected Value of Options, Warrants, and Convertible Securities, ALAN W. HARBAUGH, *Dunlap & Associates, Inc., 1454 Cloverfield Boulevard, Santa Monica, California 90404.*

D4c. Stochastic Decision Trees for the Analysis of Investment Decisions, RICHARD F. HESPOS, *McKinsey & Company, Inc., 270 Park Ave., New York, New York,* and PAUL A. STRASSMANN, *National Dairy Products Corporation, 260 Madison Avenue, New York, New York.*

D4d. Developing Objective Criteria for the Design of More Nearly Optimal Investment Decisions in Pension Fund and College Endowment Investment Management, HANS H. JENNY, *Office of Institutional Research, The College of Wooster, Wooster, Ohio.*

D4e. The Developing of Investment Strategies Through Application of Econometric Processes, J. JEFFERSON PARKS, *Parks-Ross Company, 13794 Beach Blvd., Westminster, California.*

D4f. Investment Planning Simulation, Z. SZATROWSKI, *Service Bureau Corporation, 635 Madison Avenue, New York, New York 10022.*

D4g. Dominant Decision Rule for Multistage Allocation Processes Under Risk, MARK ALFANDARY-ALEXANDER, *Operations Analysis Division, Atomic Energy Commission.*

D.5. Contributed Papers on Selected Topics in Operations Research

Location: PARLOR B

Chairman: RICHARD MEYERS, *Harbridge House, Boston, Massachusetts.*

D5a. Forecasting by Intrinsic Versus Extrinsic Models, Y. KURATANI and Y. S. CHIDAMBARAM, *Case Institute of Technology, Cleveland 6, Ohio.*

D5b. The Lockheed Multiprocessor Simulation System, John N. Maguire, *Lockheed Missiles and Space Company, Sunnydale, California.*

D5c. Military Personnel System Simulation, George O. Wright, *1000 6th Street, S.W., Apt. 206, Washington 24, D. C.*

D5d. Operations Research—or Systems Engineering—Analysis of the Relative Satellite Reconnaissance Effectiveness for Prelaunch Programming versus In-flight Operations Programming, Peter J. Johnson, *Dept. 59-16, Lockheed Missiles and Space Company, Sunnyvale, California.*

D5e. Entropy Maximization and Statistical Rescaling of Spacecraft Simulation Models, Emil M. Murad, *5316 Ocean Blvd., Long Beach, California, 90803,* and Dennis M. Galvin, *1134 Darby Street, Orange, California.*

D5f. A Mission Cost Model for Ferret Satellites, H. C. Sebring, *Missile and Space Division, General Electric Company, Philadelphia 1 Pennsylvania.*

D5g. On the Use of CEP in the Contractual Specifications of Weapons Systems: A Suggested Alternative, Melvin Brown, *Hughes Aircraft Company, Culver City, California.*

D5h. Systems Engineering and Operations Research—An Inquiry into Methodology, Robert L. Porter, *Clark Cooper, Field & Wohl, Inc., 123 High Ridge Road, Stamford, Connecticut.*

D5i. An Application of Hand-played Gaming Techniques to Subsystem Effectiveness Evaluation, Frank Ichniowski and Edward Maslansky, *Social Security Administration, Department of Health, Education, and Welfare, Washington, D. C.*

D5j. Productivity and Quality Cost Approach to Analyzing Opertor Effectiveness, J. R. Woltz, S. Soovajian, and W. Eichhorn, *I.B.M., Kingston, New York.*

D.6. Operations Research in the Insurance Industry, (A Panel)

Location: Ballroom East

Chairman: Gordon Shellard, *New York Life Insurance Company, New York, New York.*

D6a. Operations Research in Insurance.
Panelists

David H. Harris, *Equitable Life Assurance Society of the U. S.*
Leroy J. Simon, *Actuary Insurance Co. of North America*
John M. Boermeester, *John Hancock Mutual Life Insurance Company*
Nathan F. Jones, *Prudential Insurance Company*
James T. Byrne, *Metropolitan Life Insurance Company*
Bernard Shorr, *Travelers Insurance Company*
Tibor Fabian, *Mathematica*

ABSTRACTS

of the
Twenty-seventh National Meeting
of the
OPERATIONS RESEARCH SOCIETY OF AMERICA

THURSDAY MORNING, MAY 6, 1965 **SESSION A**

(9:00–12:00)

A.1. Modern Statistical Decision Theory, (*A Panel*)

Location: GEORGIAN ROOM

Chairman: RONALD A. HOWARD, *Institute in Engineering Economic Systems, Stanford University, Stanford, California.*

A1a. Position Paper, HERMAN CHERNOFF, *Department of Statistics, Stanford University, Stanford, California.*

Although I have a natural tendency to prefer the subjective psychological probability approach to inference, this approach is subject to enough criticism that I use it sparingly and sympathize mainly with the point of view that Statistics is too delicate to be subject to rigid axiomatic impositions.

Objective axiom systems often impose some arbitrary condition based on mathematical symmetries of the problem. The subjective systems lead to the existence of psychological probabilities whose origins are shrouded in genetic mystery and whose description is baffling in many problems.

I believe that the fundamental difficulty lies in the fact that the axiom systems impose requirements of consistency which include the assumption that no relevant information may be neglected. This imposition, conflicts with the real world's need to reduce complexity by ignoring information. Thus the statistician who samples from a human population uses random sampling to avoid falling into errors resulting from subtle and hidden relationships among the individuals of the population. His procedures require the tacit refusal to admit that he knows anything about the sample selected besides their responses. This conflict between the axiom systems and this vital practice carries the seeds of destruction for it is well known that any statement is derivable from the assumption of two contradictory statements.

Thus I favor the use of psychological probabilities only in problems where there is supplementary evidence that "apparently" minor changes in the psychological probabilities have minor influence on the results. As Stein has shown, this is typically not the case in multivariate problems of high dimensionality and great care must be taken in those problems.

A1b. Decision Theory as the Central Stem in an Engineering Curriculum,

MRYON TRIBUS, *Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire.*

All problems of engineering design must consider uncertainty. There are uncertainties with respect to the end use of the product, the materials of construction, the methods of construction, and the value of the product in the market place. Any method of engineering design which prepares men for professional practice must cope with these uncertainties in an intellectually meaningful way if it is to appeal to our brighter students. Modern statistical decision theory, if properly presented, is a powerful tool to assist engineers in comprehending their problems. Unfortunately, the manner in which both probability theory and decision theory has been developed makes it difficult to apply. Recent developments, particularly those by E. T. Jaynes, have made it possible to add statistical decision theory to engineering education in an easy way. In my talk I intend to demonstrate how the material is introduced by giving a few simple examples.

The most important need at the present time is for a collection of meaningful illustrations which are simple enough to be solved with a minimum of computational equipment and yet sufficiently complicated that the methods are justified.

A1c. The Problem of Applying Modern Decision Methods to Business Situations,

DOLPH G. EBELING, *General Electric Company, Schenectady, New York.*

As a result of complex defense system needs and theoretical studies, a number of probability concepts and decision theory methods have been developed in recent years. Although these methods have already proven their value in special situations, these ideas have yet to be widely applied and accepted in industrial management problems.

It appears that one of the reasons for this lag in acceptance is that these new methods require a basic understanding of probability and mathematics. It is therefore appropriate to examine the imperative need for effective educational programs covering the basic ideas and the applications of modern decision theory. In addition, there is a great opportunity for appropriate computer programs and display equipment which will permit the user to manipulate such routines as decision trees, Bayesian 'estimation, Monte Carlo simulation, and capital investment plans. In summary, the basic knowledge of these methods is available, the needs are apparent, and we now need an educational bridge to link the two.

A.2. Transportation Systems

Location: STANBRO HALL

Chairman: MARTIN WOHL, *Economics Department, Littauer House, Harvard University, Cambridge, Mass.*

A2a. A More Systematic Approach to Federal Transportation Policy, JOHN B. MEYER, *Harvard University, Cambridge, Massachusetts*

The Federal Government is involved today in many aspects of transportation development and regulation. The regulatory role is of long standing and well known. Less recognized is the fact that Federal expenditures on the development of transport facilities today total about $6 billion (exclusive of military sea and air services). Several additional proposals for transport development are now being advanced for Federal support, the most publicized being the SST and the high speed railroad for the Eastern seaboard corridor.

These very large expenditures warrant careful analysis and consideration. In some cases systematic evaluations of individual projects have been performed. Rarely, if ever, though, have different federal transport projects been checked for their consistency with each other or with the larger goals of public transport policy as expressed by the executive branch, the legislature or regulatory agencies.

To determine such consistency often would require careful and extensive system analyses in which the performance of transport facilities is evaluated in terms of impact upon at least the more important aggregate measures of national income, employment and general economic performance. Traditional benefit-cost evaluations, while useful and in most cases an improvement on present practice, can be misleading in evaluating transport investments because of being too partial, that is, by ignoring important system effects. Development of models that will gauge the interactions between general economic performance and different transport development plans or policies pose substantial problems. Some progress has been made, though, and there is every reason to believe that with modern computer techniques further progress is quite possible.

A2b. Systems Analysis and the Future of the Railroad Industry, A. S. LANG, *New York Central System, New York, New York.*

Operations research and systems analysis have had a somewhat indifferent record thus far in the railroad industry, one whose operational problems have always seemed a promising area for the application of such techniques. This paper focusses on the particularly significant promise of systems analysis as it is now beginning to be applied within the industry. It explains why railroad operations exhibit especially complex systems problems, why past efforts to subject these problems to rational analysis have been limited in their impact, and what has yet to be done to achieve greater success with such efforts.

The paper discusses the special role of operational data systems in the establishment of analytical decision-making procedures and the indispensable contribution of large-scale computer simulation. It also explains the inevitable transformation of long-run, investment-oriented decision-making procedures into short-run, operations-oriented decision-making systems and the impact of such systems upon the future of the railroads.

A2c. The Role of Systems Analysis in the Highway Transportation Industry, FRANK QUACKENBOSS, *Operations Research Department, Research Laboratories, General Motors Corporation, Warren, Michigan.*

Analysis, prediction, and control are usually the major objectives of any system study. Small scale or locally isolated systems have been effectively treated (e.g., Holland Tunnel), and the results obtained are important and interesting. A need exists for enlarging the scope of such systems studies to include a more important interaction but limited enough to permit achievement of measurement and calibration. Concepts such as road capacity, system capacity and saturation must be defined in an operational context and methodology established for model and prediction purposes. Although many urban area studies are in progress containing profound implications for the future, few if any seem to be devoted to development of suitable theory and, indeed, often rest on untested theory and assumptions. The paper concludes with a description of a subjective systems study of a road network containing both urban and rural components, and large enough in scope to demonstrate a practical and useful application of the systems concept.

A.3. OR in Real-Time Computer Systems

Location: PARLOR A

Chairman: MARTIN L. ERNST, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts*

A3a. A Criterion for Efficient Computer Storage Allocation in Real Time Systems, R. E. HEITMAN, *A. D. Little, Inc., Cambridge, Massachusetts,* and

A3b. (Continuation), M. N. PERRY, *American Airlines, Albany Post Road, Briarcliff Manor, New York.*

The objectives of storage allocation to core and to peripheral memory devices, and the possible consequences of an unsatisfactory allocation, are reviewed. As an illustration, the actual problems faced in the allocation of disk, drum, and core storage in the American Airlines SABRE reservations system are presented.

The objectives and operating characteristics of the SABRE system are described to provide the framework for establishing a criterion for storage allocation. The criterion is based on the fact that regardless of which system component actually limits throughput capacity, the limiting factor which physically prevents the processing of additional inputs is a lack of available core storage. The allocation problem is then shown to be one of minimizing the use of this quantity in the system.

The effect of increased use of any system storage component is to increase the average size of the queue serving that component. This is shown to result, both directly and indirectly, in a demand for core storage, and therefore, the planned use of any system storage component can be expressed in terms of this common quantity. In view of this, efficient storage allocation is achieved by assigning storage in components such that the net effect on demand for core storage is minimized.

The limitations in the use of the criterion proposed are discussed and a summary of much simpler but less effective criteria actually used in SABRE are reviewed. The benefits realized at each of these stages of storage allocation, as well as potential benefits from the use of the proposed criterion, are estimated.

A3c. The Real Problems of Real Time Computing, A. G. OETTINGER, *Harvard University, Cambridge, Massachusetts.*

Real time computing seems established beyond the shadow of a doubt for numerous applications where the response time of computer hardware is no longer a limiting factor. In spite of this, only a very few of the existing large scale real time systems have lived up to design expectations, if indeed they have worked at all. It is suggested that the formating, initial gathering, and updating of a reliable data base is one of the key factors often overlooked in systems design. Output data, therefore, tend to become inaccurate, or worse, uninterpretable, leading to an unstable situation where loss of confidence leads to further degradation of system performance. Design techniques for counteracting this tendency will be considered.

A3d. Priority Scheduling of Time-Shared Computer Systems, MARTIN GREENBERGER, *Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Priority decisions arise whenever limited facilities must be apportioned among competitive demands for service. Broadly viewed, even the familiar first-come-first-served discipline is a priority rule. It favors the longest-waiting user, and guards against excessive delays. Other priority rules, such as shortest-service-requirement-next, are keyed instead to considerations of operating efficiency. Urgency of request is still another common consideration. Since these considerations are often conflicting, a priority rule must serve as mediator.

A priority operation of contemporary interest is scheduling a time-shared computer system among its concurrent users. Service requirements are not known in advance of execution. To keep response times short for certain users, service intervals are partitioned and priorities made dynamic and pre-emptive.

In any automated operation, it is both easy and natural to place the scheduling decisions under computer supervision; but the design of good automatic priority procedures is not a trivial task. Direct mathematical analysis can be helpful in clarifying basic relationships, but it does not provide a flexible operating tool.

Simulation and adaptive control are more versatile techniques, but they can be overweight baggage on a production run. Most perplexing are the questions of what constitutes satisfactory customer service, and what measures system performance in meaningful terms.

A number of researchers are wrestling with these problems at M.I.T.'s Project MAC, System Development Corporation, and other time-sharing establishments. Some of their findings will be discussed, and a variety of priority procedures will be considered.

A.4. Contributed Papers on Probabilistic Models

Location: BALLROOM WEST

Chairman: JAMES M. DOBBIE, *Arthur D. Little, Inc., Cambridge, Massachusetts*

A4a. A Climate for Real Time, FREDERICK J. BURKE, *Spector Freight System, Inc., 205 West Wacker Drive, Chicago, Illinois.*

A transportation company in process of programming a large real time computer system expects the experience gained from its present serial tele-processing operation to allow it to make the transition smoothly. Primarily this expectation is based on knowledge and attitude of personnel. The work force includes a large number of individuals at decentralized locations who provide information to a central headquarters and who have learned to observe rigidly controlled formats and to make correct use of codes. At the central headquarters is a group of systems analysts, accountants, programmers and engineers, devising methods of handling information. These people have learned to stop thinking about preparation time in terms of months and weeks and to start thinking in terms of minutes and seconds. There is also a corps of managers receiving information who have grown to look for exception reports and statistically processed results rather than mere listings of transactions. The present tele-processing system, although self-sustaining from the standpoint of cost justification, was installed primarily to create a climate favorable to the real time system now being programmed.

A4b. On the Concept of FIFOV in Queues, B. KRISHNAMOORTHI, *Stanford University, Stanford, California.*

In several queuing situations, the order in which the units depart is not the same as the order in which they arrive at the system. We call this phenomenon, the "Violation of the 'First In, First Out' principle" (FIFOV). A quantitative study of FIFOV is of operational importance in tandem queuing and many other situations. In this paper we give a general discussion of the concept and study a special aspect of FIFOV in a Poisson Queue (Poisson input and exponential service times) with two heterogeneous servers working in parallel. In this connection the time-dependent distribution of the output in a M/M/1 queue has been explicitly obtained. Defining X as the number of customers superseding a customer taking service from the slower channel, we obtain the distribution and the first two moments of X under a queue discipline which is a modification of the usual one. An optimality criterion has also been suggested.

A4c. Optimum Communications Center Buffer Design, Ints Delgalvis and Richard C. Soucy, *I.B.M., Kingston, New York.*

The advent of real-time computer system has introduced many interesting design areas, applicable for Operations Research. This paper describes methods for the design of a central core storage area, required to buffer messages transmitted over communications lines between a central processor and its remote terminals. Since core storage is an expensive item relative to other storage media, it is important that the buffer area, which is usually the largest core consumer next to stored programs and whose core requirements exceed those of the latter in large systems, be designed as efficiently as possible. This paper describes and evaluates the various techniques of assigning buffer storage; it covers both static and dynamic types of core allocation and shows how to determine which one is more applicable to a given system. It further develops methods to determine optimum parameters such as block size and record size. Probabilistic techniques are used to optimally determine the amount of required core storage. Derivations take into account restrictions such as those placed by program and hardware, chaining requirements, traffic rate, message lengths, system availability, and line interference. All calculations are in a mathematical form for easy implementation.

A4d. Queueing Analysis of Real-time Computer Systems, Wei Chang and Donald J. Wong, *I.B.M., Kingston, New York.*

Recently development of the real-time environment has greatly influenced the design and altered the concepts of computer oriented systems. As the state of the art in the field of data processing continues to advance, the classical approaches to system design and analysis are rapidly becoming increasingly inadequate such that more sophisticated means must be developed. This paper will consider such areas as the communication network, the message exchange, central processor, auxiliary storage, etc. Within each area, a brief description is included for each of the following: the functional operation, the critical characteristics, the formulation and performance analysis. Many Operations Research problems are related to these types of systems. However, the subject material will be restricted to the queueing and congestion analysis of these systems. The analysis will employ several queueing models which provide the transit time (the time required to process a transaction, or a task), which is an important design criterion and the queue characteristics which determine the storage requirement and the competency of the device under investigation. Finally a survey of the problems encountered in system design is made, accompanied by an outline of the currently available solutions and the problems yet to be solved. Some of the authors' previous work on real-time systems will also be discussed.

A4.e The Application of Queueing Theory to the Design of Real-time Computer Systems, Edward W. Veitch and Walter A. Levy, *Pennsylvania Research Associates, Inc., 27 South 36th Street, Philadelphia, Pa., 19104.*

The design of a real-time computer system involves very careful consideration of the relationship between the external load and the internal system structure. The external load is frequently described in probabilistic terms. The internal structure is generally characterized by the performance capabilities of the storage or processing elements of the system and their functional relationships; the latter being essentially embodied in the computer program. Queuing Theory provides a number of models which are very useful in the design of these systems. These models can be employed to investigate such questions as the acceptability of sharing storage capacity amongst several requirements, delays in accessing certain devices, and the consequences of such delays on storage requirements and system performance. This paper will discuss the problems of designing the internal structure of a computer system and show applicability of several specific queuing models to the solution of these problems.

An illustration is the estimation of fast-access buffer storage capacity required in a multi-channel message switching communications center in which a slow-access magnetic drum is used as primary buffer for messages which temporarily overload particular output channels. Queuing Theory shows interdependencies among data input-output rates, processing speed, and drum access time. Other examples illustrate complexities of multi-processor/multi-memory real-time control systems.

A4f. The Control of Multiple-Channel Queueing Systems with Mixed Input Streams, JOHN P. YOUNG, *The Johns Hopkins University, Baltimore, Maryland.*

Two queuing models of general theoretical interest and applicability are presented. These have been derived within the context of research in the Health Services that views a hospital as an input-output system influenced by both stochastic and controllable factors. In both models, the typical hospital ward has been compared to a limited, parallel-channel queuing system with mixed input streams. In the "rate control" model, arrivals are composed of a random, Poisson distributed input superimposed on selected constant rates of input. In the "adaptive control" model, arrivals are composed of a random, Poisson distributed input superimposed on an input controlled by means of instantaneous information feedback as to the state of the system. For both models steady state probability distributions are derived, together with expressions for expected value and system variance The decision-maker exercises control over system variance and the expected number in the system through the use of decision rules dealing with the arrival process. The models are generalizable to many situations where one is confronted with a demand for service that has both random and scheduled elements.

A4g. A Simulation Approach to Evaluating the Effects of Redirecting Heteromorphic, Variable Delay, Queue Feedback in Multi-Channel, Parallel Systems, RONALD LESSING and JOHN H. MOSS, *Social Security Administration, Department of Health, Education and Welfare, Washington, D.C.*

In parallel channel queueing situations with multi-type arrivals, a given type of arrival may generate further arrivals of other types on a given channel, leading to a variety of feedback in the system which tends to make the system unstable. This analysis is devoted to an evaluation of the effects of the feedback and the feasibility of redirecting this feedback from the initial service channel to another service channel. An actual system is here described in which the types of arrivals consist of people (interviews), paper work and communications (mail and phone) resulting from the interview service, and development inputs, also consequent to the interview service. If one randomizes the interview arrivals on the parallel service channels, the effect of the feedback is to unbalance the load distribution across the service channels. By redirecting the "feedback arrivals" to alternate service channels, this loss of system stability is compensated. Mathematical approaches to this problem have led to limited insight. Accordingly, in this simulation the effects of random and/or scheduled redirection of "feedback arrivals" is assessed.

A4h. Sensitivity Analysis of 473L Performance, STANLEY B. ROSEN and ESSIE S. NEVANS, *General Electric Company, Information Systems Operation, 4901 Fairmont Avenue, Bethesda, Maryland.*

The 473L System was analyzed to determine expected system response time for a wide range of operating conditions. An abstract model of the system was constructed and used to investigate queuing problems associated with the general purpose computer and content addressable disc. System performance was estimated through analytic and simulation studies. The assumptions on system operating characteristics and loads and the model will be discussed. Predicted System response time and utilization of the computer and disc will be given showing their sensitivity to major system parameters. This study demonstrated the usefulness of modeling coupled with analysis and simulation for system design even when quantitative data on system loads is not available.

A4i. An Operational Readiness Model for an Inertial Navigation System, J. J. MALTESE, *Autonetics, 3370 Miraloma Ave., Anaheim, California, 92803,* and R. A. NELSON, *Vitro Laboratories, Silver Spring, Maryland.*

An Inertial Navigation System is provided on board a vehicle. Maintenance capabilities and logistics support are provided in the system. The customer has directed that the system be designed to exceed a prescribed operational readiness. Reliability, repairability, logistics, and maintenance equipment are the categories of parameters considered. The number of failures requiring repair and realinement in an interval of time is assumed to be Poisson distributed. Also, the distribution of times to failure is assumed exponential. Similar assumptions are made for the service times as the repair and realinement activities. Under these assumptions, queuing theory is applied to derive an operational readiness model for the system. Many analyses of operational readiness are based on the combinatorial approach and are limited to mathematical manipulations with the ratio of system *up time* and the sum of *down time* and *up time*. Application of the combinatorial approach to the system does not adequately reflect the effect of realinement, insufficient spares and maintenance equipment, and non-repairable failures. To show these limitations, an analysis is included whereby the results of the queuing theory approach are compared to those of the combinatorial approach. An analysis is also included to evaluate the effects of "cannibalization".

A4j. Operations Research Study in a Telephone Company Business Office,

JOHN M. HOLMES, JR., *The Chesapeake and Potomac Telephone Company of West Virginia, 1500 MacCorkle Ave., Charleston, West Virginia.*

The work load or demand in a telephone company business office was divided into two classes: (1) customer telephone contacts which were nondeferrable, and (2) clerical work which was deferrable. The analytical work was performed on the non-deferrable demand, while the deferrable clerical demand was used in simulation models for completeness. The empirical distributions of both customer telephone contact arrival rates and lengths were compared to theoretical distributions. When statistical tests did not show a good fit, a computer simulation program was written using the GPSS language. Both theoretical and empirical data were run on two simulation models. The results and implications are reported. Also it was recognized that the telephone contact demand was very similar to the demand in a central office which can be handled with queueing models. The use of queueing models produced relative results, but for total force requirements a simulation model was required. The reasons and results are explained. In addition the models were used as a design tool to test a proposed change in a business office. And finally a deterministic model was used to estimate the effect of a random access computer on office operations.

A4k. Analysis and Projection of the Historic Pattern of Supply of Exhaustible Natural Resources.

C. L. MOORE, *Box 582, Benjamin Franklin Station, Washington 44, D. C.*

In the exploration and exploitation of exhaustible natural resources, such as petroleum, the projection of the long-term supply of these resources is a prime factor influencing decisions for planning investments and in formulating policies. This paper presents a logical derivation of the Gompertz equation as a solution to this problem. Presented also is a more concise method of fitting data to the Gompertz curve than that given in textbooks. The method presented herein is being used for long-term projections of supply of crude oil, and of natural gas, on a world-wide regional and country basis. A typical example is given for one major oil-producing region of the United States. The correlations between the actual historic data and that calculated by Gompertz equations on four different components of supply, vary from .976 to .999 covering periods ranging from 24 to 36 years. The projections of the four components were consistent with each other. These typical results, coupled with the logical derivation given for the Gompertz equation as applied to this problem, merit consideration of this method.

A.5. Contributed Papers on Design of Information and Control Systems

Location: PARLOR B

Chairman: KENNETH W. YARNOLD, *Dunlap & Associates, Darien, Connecticut*

A5a. Establishing Objectives, Measures, and Criteria for Multi-Phase Complementary Activities,

Sidney I. Firstman and David S. Stoller, *The RAND Corporation, 1700 Main Street, Santa Monica, California.*

In order to translate overall system objectives into operationally meaningful concepts for planning and evaluation, it is necessary to establish subobjectives for each of the phases of a multi-phase activity, and also for each of the complementary activities within each phase. Subobjectives for each phase should support the achievement of the system objectives, and the complementary subobjectives within each phase should combine to yield the phase subobjectives. Within each phase and activity, depending on the subobjectives, primary and secondary measures and criteria are constructed to ascertain progress toward (or retrogression from) the achievement of the subobjectives. Two particularly appropriate classes of measures and criteria are defined by a (1) time-limit-probability structure and a (2) within-limits structure. It is not always possible to structure subobjectives so that the within-phase and within-activities measures and criteria are completely concordant, and methods for overcoming this difficulty are discussed. Examples of the process and concepts described above are given in the context of generalized countdown and launch-commit activities.

A5b. Requirements Analysis and Its Impact on Command System Design,

John A. Evans, *Information Sciences Department, The MITRE Corporation, Bedford, Massachusetts.*

The purpose of this paper is to discuss the important relationship between requirements analysis and the command system design process. Selected aspects of the conceptual design activities which were performed in connection with the evolutionary design of a planning-oriented command system for a unified command are illustrated in order to highlight this relationship. Initially, an overview of the command system design process is discussed as a means of providing a contextual framework. In concluding this overview, some of the unique characteristics of a command system which complicate requirements analysis are identified. Subsequent discussion addresses the following questions: (1) What information should a command system requirements analysis contain? (2) Why is it needed? (3) How are its products jointly used by the system design organization(s), the "user" command, and higher level commands in the development of applicable design alternatives and in the control of the design process? The requirements analysis products, which convey an understanding of the command's operational environment and an understanding of how major command functions are executed, are reviewed. Operational plan generation and modification (crisis re-planning)—a major command function—is discussed in greater detail. Effectiveness criteria, which were derived from the requirements analysis and which are useful in evaluating alternative design approaches to increasing command planning capabilities in view of future requirements, are identified. In concluding, some of the major planning-related tradeoffs are discussed.

A5c. System Reliability in an Electric Utility, BURTON V. DEAN, *Case Institute of Technology, Cleveland, Ohio, 44106*

Both system engineering and operations research have been concerned with the problem of designing technologically based systems for improving and controlling operational reliability. The system engineer usually attempts to design an optimal system to meet specified goals for reliability performance, whereas an operations research study will usually include an attempt to relate costs and effectiveness so as to allow for both selection of performance level and specification of system costs. The electric utility industry provides an excellent opportunity to apply new methods in operations research to old problems in system engineering. Although major advances have been made in the design of reliable power generation and distribution system components, such as boilers, generators, transformers, circuit breakers, and relaying equipment, significantly less is known about the reliability of complete systems. This paper presents a model for use in the design of an adaptive reliability control system for an electrical utility.

A5d. Exercising the Modern Command System, W. H. TETLEY, *Cornell Areonautical Laboratory, Inc., Buffalo, New York, 14221.*

The design of a Military Command System is in part an evolutionary process. As modern weapon systems are acquired by operational units, the spectrum of choices open to the Commander becomes so broad that he must in turn acquire sophisticated tools to assist him in his decision-making responsibility, and in the exercise of his judgment. The choice of appropriate tools is a relatively difficult task for it involves people, procedures and machines together with all their interfaces. The scenarios for the traditional CPX (Command Post Exercise) tended to examine, and to some extent evaluate, the interface between people, both vertically (up and down the Command chain); and laterally between commanders. In exercising a modern Command System, however, the scenario must consider in addition the man-to-machine and machine-to-machine interfaces; as well as how procedures and methods impinge on these. The cost of exercising a large command system is so enormous that apriori assurance of meaningful results is essential. This has stimulated an inquiry as to which relationships should be explored, their nature, and the type of gaming which is appropriate. Above all, what is to be tested must be determined, and how the results are measured and interpreted must be clearly prescribed.

A5e. Determining a Measure of Effectiveness for a Command and Control System, J. E. GERNOGROSS and F. J. HUDDLESTON, *Command and Control Department, Defense Systems Division, The Bunker-Ramo Corporation, 8433 Fallbrook Ave., Canoga Park, California, 91304.*

During the study phase of the MMRBM Command and Control System, many individual trade-off studies were performed to aid in the choice of optimum values for critical parameters in the system design. In evaluating these studies, the problem arose that the various requirements for the system conflicted with each other. The usual method of handling several objectives is to determine the relative importance of the various objectives, weigh each objective accordingly and sum the weighted efficiencies to determine the relative effectiveness of the system. The problem arises in objectively rating the various objectives; and then in obtaining universal agreement of the ratings. This paper will discuss the various conflicting requirements for a command and control system, and the method evolved for determining the performance of the system design in response to these requirements without subjective weighting. The technique is applicable to other system evaluations.

A5f. The Design of Command and Control Systems for Task Groups,

LAWRENCE E SCHLESINGER, *George Washington University, Washington 6, D C.*

The design of efficient and acceptable management systems for the command and control of "task groups", groups of interacting persons with a specific objective —a research team, committee, military crew, or office staff—is critical for organizational productivity. Design guidance based on principles of administrative management or behavioral research on group functioning is helpful, but not sufficiently delimiting. A more efficient design procedure would require (1) identification of the variables relevant to effective group functioning; (2) grouping of these variables into relatively independent sub-sets, and (3) and solving the design problem of each independent sub-set separately so that they can be combined into an overall solution. The sources of the critical variables in the management system are (1) characteristics of the major components of the system: the task group manager, members, task environment, and task, itself; and (2) communication and control linkages between these components. This paper reviews the variables that have been identified in research studies as critical to effective group functioning, their clustering into relatively independent sub-sets, and the relevant design implications.

A5g. Operations Research as a Money-making Management Tool in Small Production Runs of Electronic Equipment,

JAMES A BIRDWELL.

The use of Operations Research techniques to maximize profits in repetitive manufacturing processes is well established. In the case of developmental programs, these same techniques are used to assess the time-risks involved in alternate technical paths. Even though OR is widely used in these cases, most managers fail to consider OR in operations involving small production runs. This paper offers some guidelines to be considered in the use of these modern management techniques with small production runs of electronic equipments, including the necessary modifications to the classical approaches. The necessity of rapid accounting feedback to verify the model and to pin point new areas for OR consideration is discussed. The organization of budgets, production, engineering, and purchasing to permit the effective use of OR in small production runs is outlined. An actual example of profit improvement due to the use of OR is discussed. The example is based on two contracts for the same electronics equipment at the same bid price. Finally, it is shown that the use of OR not only improved profit, but also resulted in the delivery of improved equipment.

A5h. Evaluation of Alternate File Structures for Command and Control Systems, Stanley B. Rosen and Essie S. Nevans, *General Electric Company, Information Systems Operation, 4901 Fairmont Ave., Bethesda, Maryland.*

Studies were performed to determine how redundancy of data can be used to reduce search time in response to single-user command and control system queries. Attention is focused on the function of retrieval from a large data base. Since searching comprises a major proportion of the time required to answer a query, various file structures whose use would significantly reduce search time were considered. Equations were derived which allow a quantitative comparison between alternatives. The particular file design to be discussed is that of a directory in conjunction with serial files. By categorizing information only a relatively small part of the file need be retrieved and tested. It was concluded that system performance can be greatly improved by applying the equations and analysis described to specific systems.

A5i. Project Cost Curve—Equivalent Linear Graphs, V. K. Handa, *Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada.*

The extension of Critical Path planning models dealing with the determination of the project cost for all feasible durations has not been used extensively by industry, although mathematical techniques and computer solutions to the problem have been widely available. One of the reasons is the requirement of complete data—crash completion time, crash cost, normal completion time and normal cost—for each and every operation of a project, even though only a fraction of these operations is pertinent to the project cost curve solution. The paper presents a linear graph model of the project cost curve problem. Original theorems are developed to identify the redundant or non-critical operations in a project. Discarding the non-critical operation results in an equivalent graph composed entirely of critical and sub-critical operations. In the majority of cases, this leads to a very simple solution of the project cost curve.

A5j. Testing for Error Contributions in Certain Man-Machine Control Systems, Stanley P. E. Price, *Federal Aviation Agency, NAFRC RD-713, Atlantic City, New Jersey.*

A sequential operation man-machine—or all hardware—control system comprised of n series elements is considered. A systematic method of testing and subsequent analysis is described which isolates error contributions from individual elements and provides a framework for analytical investigation of the effect of variation of individual element performance. A known system input message results in measurable outputs from the following series elements. The error contributed by the i^{th} element is given by a linear equation which is a function of the measured outputs and a set of corresponding pre-computed 'no error' values. Intermediate recomputations are therefore not necessary. Considering the errors so obtained as independent random variables, use is made of the Moment Generating Function to illustrate the steps from data acquisition to analysis. Using normal distribution of errors, the ease of subsequent pencil and paper investigation of the effect on the system error distribution of changing the nature of the individual element error distributions is shown. The utility of such an undertaking in aiding decision-making in terms of quantifying certain cost-benefit relationships before purchasing a computer system is discussed for an example taken from Air Traffic Control.

A5k. On the Use of Discriminant Analysis for Establishing Decision Rules, J. Zelnick.

The problem of developing decision rules for discriminating among alternatives is an acute one in many different types of management situations. For example: 1) In selecting personnel, the company must make a decision on whether they should or should not hire an individual. 2) In selecting a vendor, a buyer must make a similar decision in regards to a vendor. 3) In granting a credit, the credit analyst must differentiate a good risk from a poor one.

There are many similar types of problems of classification faced by management every day. The wrong decision in any one of these cases can result in large monetary losses. Consequently, for optimal results, decision rules applied to these situations should be based upon a scientific methodology rather than random choice.

The scientific methodology which can be used to obtain optimal results combines a statistical technique known as discriminant analysis with a simulation program. This methodology accomplishes the following results: A) Determines the relevant variables. B) Weights these variables. C) Selects a standard score for establishing a decision rule.

This approach has been successfully applied in credit evaluation and personnel. In terms of the credit application the following advantages were achieved: (1) All credit managers use the same system, thereby reducing individual differences among them. (2) The number of items on the application blank is reduced. (3) The amount of bad debts incurred is reduced by about 20%. (4) Accurate estimates of savings can be made by diagnostic programs before the system is implemented. (5) If the total system is used, the number of credit inquiries is reduced because of the use of the screening mechanism of the credit application form.

THURSDAY NOON, MAY 6, 1965 LUNCHEON

(12:15–1:45)

Location: Ballroom East

Speaker: Marshall K. Wood, *Director*, *Economic Programming Center*, *National Planning Association*

Subject: **Quantitative Approaches to Public Policy Formation**

THURSDAY AFTERNOON, MAY 6, 1965 SESSION B

(2:00–5:00)

B.1. Systems Engineering or Operations Research, A Panel

Location: Georgian Room

Chairman: William K. Linvill, *Stanford University*, *Stanford*, *California*.

B1a. Systems—Profession Born of Technological Advance, William K. Linvill, *Stanford University, Stanford, California.*

Technological advances in computers, communication, and control have paved the way to development of the system area. The upper limit to the size of an effective system in the past was set by the ability to coordinate the parts. Automatic data processing has removed this constraint and now external factors such as economic value or rate of social acceptance set the limits on size. Analysis and design of systems now simultaneously involve both engineering and management problems. Insofar as system engineering sticks to physical system problems and operations research sticks to operational system or management problems, both are failing to serve today's needs.

System development and design involve a match between society's immediate demands on one hand and present technological ability on the other. System planning involves long-range projections of society's needs on one hand and of technical feasibility on the other, but with much less detail than can be supplied in near-at-hand problems. System research is the longest range of all. It involves patterns of objectives, patterns of realization, and processes of optimization to combine the two. Thus the scope of the system field must include both hardware areas of engineering and human problems of management. It must range from the specifics of design to the abstractions of research.

B1b. Position Paper, R. L. Ackoff, *University of Pennsylvania, Philadelphia, Pennsylvania.*

System engineering is primarily concerned with the design of physical (mechanical, chemical, or electronic) systems. OR is primarily concerned with evaluating the performance of actual or proposed systems in which human (individual or collective) behavior plays a major part. Nevertheless, many of the concepts and mathematical techniques employed by the two are the same or similar. The two interdisciplines can interact fruitfully where OR evaluates the operation of a proposed system designed by system engineers and feeds back inputs into successive redesign stages.

Design usually requires dealing with larger numbers of variables and relations than does evaluation. Hence, all possible designs can seldom be formulated let alone evaluated; hence, optimization must usually be replaced by satisficing. For these (and other) reasons the methodology of design must differ from the methodology of evaluation. Some of these differences will be identified and discussed.

B1c. A Systems Engineer Looks at Operations Research, Robert E. Machol, *Systems Engineering Department, University of Illinois, Chicago, Illinois.*

It has long been clear that the viewpoint of operations analysts and system engineers are very similar, but that they tend to seek out different types of problems; namely, the operations research man is most at home with a problem in which an operation exists and the tactics or operational methods are to be optimized, while the system engineer feels happier when he is given a problem in which a present system is being completely redesigned, or a new system is to be constructed, and he can become deeply involved in the design of hardware. From the viewpoint of one presently engaged in designing a curriculum for the education of system engineers, this reflects itself in a different type of technological background. While both require heavy training in mathematics, the more the better, the system engineer must be just that—namely, an engineer—and he must have a solid grounding in a number of facets in modern engineerings. The comments in this presentation will be centered around the education of modern system engineers.

B1d. Position Paper, ARTHUR D. HALL, *Television Engineering Department Bell Telephone Laboratories, Murray Hill, New Jersey.*

Operations Research and Systems Engineering may be seen as independent, overlapping, or one wholly included within the other, depending upon the factor of comparison and the point of view In this talk, the two fields will be compared relative to their histories and current trends, methodologies, tools, and objectives The purpose of the comparison is to point to useful similarities, to preserve equally useful distinctions, and to suggest opportunities for future collaboration.

B.2. Design of Command and Control Systems

Location: STANBRO HALL

Chairman: JOSEPH H. LEWIS, *Institute for Defense Analyses, Weapons Systems Evaluation Division, The Pentagon, Washington 25, D. C.*

B2a. Requirements—The Illusive Elements in System Design, JOEL N. BLOOM, *Industrial Engineering Laboratory, The Franklin Institute, Philadelphia 3, Pennsylvania.*

In the beginning of the design of command support systems there is a word: REQUIREMENTS. These requirements cannot be stated a priori uniquely and completely because the command organism must be responsive to the techniques which different commanders select to solve the problems which arise in changing environments and situations.

Based on a preliminary statement of requiremens, an initial system design strives toward

1. *Early operational capability.* This capability must meet the initial requirements in terms of objective crtieria to the satisfaction of both commander and staff.
2 *Capability for ongoing system modifications and refinements.* Systematic continual analysis of system operation must be provided to modify and expand requirements based on user experience with the initial system, on changes in the system environment, and on additional or changed demands placed on the system.

Later system designs consist of successive iterations of the initial-system design.

This approach affects the design concept of the subsystems. For example, in the personnel subsystem, use of in-house military user/analyst personnel must be emphasized. The hardware subsystem must be based on successive installations of modest equipment which can be procured by rental or purchase and activated rapidly. Initially, the software subsystem must draw on existing computer programs with the development of sophisticated software deferred to latter stages. The facility-subsystem design should be based on using existing facilities, supplemented by modest construction which will encourage experimentation and change.

B2b. Application of Information Flow Studies to Development of Command Support Systems, Robert H. Adams, *Institute for Defense Analyses, Weapons Systems Evaluation Group, Pentagon, Washington, D. C.*

Information flow research has become an integral part of studies of the ability of military staffs to react to and support crisis operations. Perhaps more important conclusions have resulted from analysis of information flow within a headquarters than from the more conventional message traffic analyses between headquarters. Development of information flow patterns under emergency conditions to indicate information distribution points, action offices and functions at various echelons, and decision times at each echelon has been informative in showing, for example: (1) How special security provisions modify standard and planned emergency procedures for staff support; (2) The importance of checklists and other staff work in existence prior to an emergency arising; (3) The need for feedback from top echelon decision-makers to subordinate staff members to allow follow-up coordination on actions ordered away from headquarters; (4) Classification of periods of staff activity during emergencies to fit specialized types of staff personnel needed in initial and subsequent periods; and along with normal message traffic analyses, (5) Quantitative communication capabilities, time delays in information transmission, and over-loadings on communication facilities.

B2c. An Approach to the Design of Command and Control Systems, W. F. Bennett, *Washington Systems Center, I.B.M., Bethesda, Maryland.*

The purpose of this paper is to describe some of the developmental activities necessary to the design of large scale command and control systems. Developmental activities associated with the design of System 473L will be used as an example. System 473L is a large scale command and control system being implemented for Headquarters, USAF, to facilitate effective management of USAF resources particularly during emergency situations. When fully operational, the system will consist of numerous computational capabilities implemented on two high-speed data processors supported by automatic data links, several types of output devices, and numerous operator consoles. This paper will describe the developmental environment and the approach taken to satisfy the objectives of the system. Major developmental activities and their relationship will be described in terms of objectives and scope. Personal observations regarding developmental considerations having a significant impact on the design of large scale command and control systems will also be presented.

B2d. Technical and Monetary Management of the Development of Command Support Systems—A Continuous Activity—The Relationship of Funding Procedures to Development Problems, Robert H. Scherer, *Asst. Deputy Director of Defense Research and Engineering NMCS (TS) and Strategic Command and Control, Department of Defense, Washington, D. C.*

B.3. Earth Science Applications of Operations Research

Location: PARLOR A

Chairman: DOUGLAS L. BROOKS, *The Travelers Research Center, Inc., Hartford, Connecticut.*

B3a. The Exploitation of Geophysical Information in Naval Operations,

GEORGE H. MILLY and JOSEPH G. BRYAN, *The Travelers Research Center, Inc., Hartford, Connecticut.*

The problem of formally defining the utilization of geophysical information and prediction has arisen in the context of naval operations which are sensitive to environmental influences. A generalized formulation has been developed in which the extent to which geophysical information can be exploited in an environmentally affected operation depends on (1) the establishment of an output measure Z of the performance of a system (operation), (2) the determination of system sensitivity of Z to appropriate geophysical variables, (3) the decision options available to the system operator (commander) in response to geophysical information, (4) the precision with which the geophysical conditions which affect the system (operation) can be estimated from information available in advance of decision, and (5) the form in which estimates of geophysical conditions are expressed.

The output Z on a particular occasion will depend simultaneously upon controllable factors c, broadly identified with the level of effort expended, attendant circumstances a, other than geophysical, and geophysical conditions g. When only a portion of the variability of Z can be accounted for in terms of values assigned to the recognized variables, the narrowest possible specification of Z is defined by a conditional probability function $\Psi(Z \mid c, a, g)$, in which all assigned variables (a, c, g) are treated as parameters.

In the nature of geophysical phenomena, the values of g that are concurrent with the operation cannot be known exactly in advance, when the operational decision is made. Consequently, the exploitation of geophysical information ultimately rests on a prediction. The logical consequence of introducing a prediction is to eliminate the variables g and replace them by an auxiliary set of ascertainable substitutes, or predictors, S. Let $\Gamma(g \mid S)$ denote the multivariate conditional distribution function of g, with S prescribed. With S replacing g, the specification of Z in terms of c, a, S is defined by another conditional distribution function $F(Z \mid c, a, S)$ where

$$F(Z \mid c, a, S) = \int_{g} \Psi(Z \mid c, a, g)\, d\Gamma(g \mid S)$$

In principle, the connection between forecast and operation resides in the probability distribution function $F(Z \mid c, a, S)$ and enters via the probability distribution of g given S. A forecast becomes functional in decision making when, by projective assimilation of available data, it helps to specify the probability distribution of the system output. Its role is to assist the decision maker in choosing an appropriate course of action, by enabling him to weigh the risks entailed in the options at his disposal. The purpose of the proposed formalism is to provide a rationale whereby the environmentally influenced risks can be specified.

The generality of the formulation introduced here is illustrated by showing how the cost-loss matrix conventionally used to represent forecast ability may be identified as a special situation. The potential of this generalized formulation is also suggested by its ability to clarify hitherto unstated and implied assumptions in the cost-loss matrix method. A brief description will be given of plans for a program of system evaluation by means of the general theory, in which $\Psi(Z \mid c, a, g)$ is evaluated using system simulation techniques.

The work being reported is part of a broader study conducted under contract with the Office of Naval Research.

B3b. The Difference Between Weather Forecasters and Weather Advisors,

R. R. Rapp, *The RAND Corporation, Santa Monica, California.*

During the last half of the last century, those natural philosophers who had been attempting to understand weather phenomena were called upon to organize weather services. Knowledge of the atmospheric processes was meager, but the weather advisories issued by these services were considered to be sufficiently useful to warrant their expansion in most countries and the formation of international organizations to provide weather data.

While twentieth century science has improved our understanding of the atmosphere, it has not kept pace in its ability to provide advice to those who could benefit from this increased knowledge. It is apparently no longer possible for the meteorologist to communicate directly to the user. It is suggested that our improved, but still imperfect, knowledge of the atmosphere can best be transmitted by creating a link between the meteorologist and the user. This link, which has been personified by the term "weather advisor," would combine the operational requirements of the users with the weather information of the meteorologist to produce advisories with direct application to the problem. The application of decision theory to properly stated forecasts might well produce the best advisories.

B3c. The Synthesis and Use of Long Hydrologic Records in Resource Planning,

Myron B. Fiering, *Harvard University, Cambridge, Massachusetts.*

The design and operation of a multi-purpose, multi-structure water resource system provide a fertile source for operations research problems. Planners are confronted by intractable difficulties in formulating objective functions and technologic functions; typical complications include political constraints, uncertainty surrounding hydrologic inputs and economic demands, measurement of nonmarketable outputs such as water-based recreation and flood control, and specification of an appropriate discount rate. To these economic and political issues we must add the details of hydraulic, geologic, and agricultural technology—the composite problem taxes our fastest computers and most imaginative designers.

This paper deals with the status of research efforts directed at resolving the implications of hydrologic uncertainty. The thrust of the suggested analysis is digitals simulation of the prototype system, the model being subject to long sequences of exogenous variables which were not actually observed but which, by any ordinary test of statistical significance, are indistinguishable from the real record. The paucity of hydrologic records at most streams, and the enormous investments at stake, make it mandatory to utilize the available data in the most efficient manner. Traditional techniques, incorporating only the observed sequence or some "critical" portion extracted from it, fail to utilize all the information contained in the data, and are thus inefficient techniques.

Analytical results and case studies based on the synthesis of records will be given; areas where applications of the model appear fruitful will be discussed.

B3d. Resource Planning in Ocean Surveys, HAROLD NISSELSON, *Operations Research Incorporated*

A national ocean survey program has been projected by the Interagency Committee on Oceanography that would attempt to survey a major portion of the world's oceans over the next 10 years. The resources of the Federal Government aside from those engaged in military oceanography and institutional research are in the process of being developed and organized. An operations research study sponsored by the Coast and Geodetic Survey, U. S. Department of Commerce, was undertaken in 1963 to develop tools for determining the requirements for ships, instrumentation, personnel, and facilities that will be needed to accomplish a comprehensive federal program in ocean surveys in an effective and economical way. This paper describes the results of all phases of the study to determine the type of ocean survey ship which would most economically be able to accomplish survey program effectiveness. The model, which was developed to analyze ocean survey ship performance in sample measurement programs of a worldwide ocean survey program, also permits estimation of a total effort required and the total cost for the most efficient program which can be designed.

B.4. Contributed Papers on Methods and Applications of Decision Theory

Location: BALLROOM WEST

Chairman: GORDON M. KAUFMAN, *School of Industrial Management, Massachusetts Institute of Technology, Cambridge, Mass.*

B4a. Reliability Statements Under Uncertainty, WARREN G. BRIGGS, *Harbridge House, Inc., 11 Arlington Street, Boston, Massachusetts.*

The probability of a successful mission (i.e. reliability) for an electronic system is often described as a POISSON process, whose failure rate is assumed to be known. This paper shows how subjective estimates, limited test data, or both can be used to compute better statements of reliability under such uncertainty regarding the true failure rate Techniques for expressing subjective estimates are described, along with a Bayesian procedure for incorporating subsequent test data. A simple method of computing the resulting negative binomial distribution of failures is shown.

B4b. Optimum Policy Regions for Markov Processes with Discounting, Richard D. Smallwood, *The Institute in Engineering-Economic Systems, Stanford University, Stanford, California.*

The Markov process is a useful model of many operational systems in which decisions must be made that are dependent on the state of the system. In this case, the real world decision policy can be modeled as the selection of a set of transition probabilities and rewards for each possible state of the Markov process. The policy iteration technique developed by Howard is a powerful tool for calculating the optimum decision policy for the process if a very large number of transitions are to be made and future rewards are discounted. In any practical application, however, the discount factor may not be known exactly. In this case, it becomes important to know how the optimum policy depends on the discount factor. This paper considers the problem of determining the regions of the discount factor for which the same decision policy is optimum. An iterative technique is described for finding the critical values of the discount factor for which two or more policies are optimum. In addition, a relation for the derivative of the total expected reward with respect to the discount factor is derived. The results will be illustrated with a simple example.

B4c. A Decision-Theoretic Evaluation of an Idealized Bomb-Damage Assessment Information System, Ugo O. Gagliardi, *Dunlap and Associates, Darien, Connecticut.*

The decision task considered is that of scheduling restrikes against a partially destroyed set of targets while obeying certain constraints regarding the availability of weapons. The decision rules sought are those which maximize the conditional expected utility given the bomb-damage report received. The computation of these conditional utilities requires the formulation and use of a stochastic model for the noise (error) scattering processes which prevail in the information system being used. The difference in expected utility, resulting from the adoption of the information system, is used as a measure of its effectiveness in supporting the decision maker. The determination of the decision rules leads to a convex programming problem for which the Kuhn-Tucker conditions yield a complete resolvent algorithm.

B4d. Hypothesis Testing in Command and Control, H. Gumbel, *Lockheed Missiles and Space Company, Dept. 51-34, Bld. 102, 111 Lockheed Way, Sunnyvale, California.*

In the design of Command and Control systems, relatively little attention has been directed toward a firmer foundation for the essentially dynamic nature of the command decision process.

This paper attempts to view this process in the light of modern sequential decision theory. While the rigorous statistical approach is frequently inapplicable many principles can be incorporated. The requirements for functional system design, data processing and display which derive from the proposed approach are also discussed and illustrated.

B4e. The Constant Likelihood of the Residual Hypothesis in Bayesian Statistics,

Raymond H. Burros, *System Development Corporation, 45 Hartwell Ave., Lexington, Massachusetts*

Whenever each of a finite set of mutually exclusive hypotheses is to be tested by observation (as in pattern recognition) a *residual hypothesis* is required to account for the possibility that all the original hypotheses are false. A prior probability distribution is postulated over the enlarged finite state space. The prior probability of the residual hypothesis then measures the *prior doubt* about the original set of hypotheses. For each of these, a multidimensional likelihood density is postulated over the bounded continuous sample space. A constant multidimensional likelihood density is then deduced for the residual hypothesis from two postulates: (1) The residual likelihood is a never increasing function of the other likelihoods. (2) When marginal densities are obtained by integrating out any specified observable variables, the marginal density for the residual hypothesis is proportional to the previously mentioned never increasing function of the corresponding marginal densities from the other hypotheses. Then, after a vector of observations is obtained, the posterior probability distribution may be computed over the enlarged state space by Bayes' Theorem. The posterior probability of the residual hypothesis then measures the *posterior doubt* about the original set of hypotheses.

B4f. Methods of Measuring Utilities Under Independence,

Peter C. Fishburn, *Research Analysis Corporation, McLean, Virginia, 22101.*

This paper describes a set of methods for constructing an individual's utility functions for the n criteria in a multiple criteria evaluation situation under the assumption that the basic utility function φ can be written in the additive form $\varphi(x_1, x_2, \cdots, x_n) = \varphi_1(x_1) + \varphi_2(x_2) + \cdots + \varphi_n(x_n)$. The methods for constructing the φ_i include a gambles approach, a direct assignment method, and several nonprobabilistic procedures based on indifference judgments involving two criteria at a time

B4g. On the Expected Gain of a Markov Chain with Uncertain Transition Probabilities,

J. J. Martin, *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.*

In this paper a Markov chain with rewards is considered in which the transition probability matrix, **P**, is uncertain. Expressing this uncertainty in the form of a prior probability distribution, $F(\mathbf{P}|\boldsymbol{\psi})$, with parameter $\boldsymbol{\psi}$, it is shown that, assuming F satisfies a mild continuity requirement, the expected value of the n-step transition probability matrix approaches the expected value of the matrix of steady-state probabilities as n goes to infinity. Making the additional assumption that F is a natural conjugate distribution relative to the data-generating process of the Markov chain, functional equations for the mean and variance-covariance of the steady-state probability vector, $\boldsymbol{\pi}$, are derived, where these expectations are regarded as functions of $\boldsymbol{\psi}$. These results lead to functional equations for the mean and variance of the gain, or expected reward per transition in the steady-state. Methods of solving these equations are discussed. Particular attention is given to approximating the expected value of $\boldsymbol{\pi}$ and the expected gain by the steady-state probability vector and the gain of the Markov chain governed by the mean of the random matrix, **P**. Error bounds are derived for this case. The paper concludes with some numerical examples.

B4h. Hierarchically-Structured Sequential Decision Processes: A Bayesian Decision Theory Model, Marvin L. Manheim, *Directorate of Transportation, Office of the Deputy Chief of Staff/Logistics, Headquarters U.S. Army, Nassif Building, Washington, D. C., 20315.*

This paper describes an extension of the classical Bayesian Decision Theory model which explicitly considers (a) the multi-level nature of many real problem-solving processes, and (b) the generation of alternatives over time. Highway location is used as an example, but the formulation is general.

A Single-Level Operator is defined as any set of procedures for (1) generating an action, (2) predicting its consequences, (3) evaluating the predicted consequences, and (4) ranking the action relative to others previously generated and examined. Operators can have different costs (per action produced) and "levels." We say that operator A is of higher level than operator B is any single action generated and examined by A can be interpreted as a set of actions of the type generated and examined by operator B. For example, in highway location a number of detailed highway construction plans, although different in some details, will be sufficiently alike to be represented by a single "location." Therefore, the operator for generating and examining locations is of higher level than the one for construction plans.

In the class of problems of interest, the problem-solver has a choice of several operators, with different costs and levels. He uses an operator to generate and examine an action; then, he must decide whether to terminate the process, or, if not terminating, which operator to use next. Bayesian Decision Theory, extended to accommodate actions of different levels, can be used to compute the best strategy in this hierarchically-structured sequential decision process.

B4i. Relevance of Statistical Decision Theory to Fault Isolation, Richard J. Matteis, *Dunlap and Associates, Inc., Darien, Connecticut.*

The use of statistical decision theory in the analysis of fault isolation problems is examined. The fault isolation problem is analyzed as a game with experimentation. The no cost experiment case and situations where the experiment costs the decision-maker time, dollars, etc., are investigated. The statistical decision theory approach is compared with other fault isolation procedures, such as the half-split technique and the Firstman-Gluss search rules. The potential use of statistical decision theory as a normative theory for the evaluation of training, information presentation, and computer aids in the fault isolation context is discussed.

B4j. Optimum Bayes Strategies in Truncated Life Testing, Robert J. Martel, *Technical Operations Inc., South Avenue, Burlington, Massachusetts.*

Bayes preposterior analysis is applied to the estimation of failure distribution parameters of *a priori* highly reliable components from a truncated life test. Truncation rules that are optimum in the Bayes sense are developed for typical cost structures and exponential, gamma, and Weibull failure distributions. The efficiency of this procedure is compared with classical maximum likelihood and confidence interval estimates. The most significant result is that maximum use is made of prior information about component reliability, and the terminal loss of an operational failure is treated explicitly in the analysis. Consequently, parameter estimates (and corresponding reliability estimates) are improved optimally even when a truncated test results in no failures. A particularly relevant application is the reliability testing of electronic components destined for use in advanced space missions, where the *a priori* mean-time-to-failure is on the order of 10^6 hours, there is a fixed time constraint on the duration of testing, and terminal loss strictly dominates sampling costs.

B4k. Generation and Simulation of Attributes Sampling Plans with a Detailed Analysis of Wald's Sequential Probability Ratio Plans with Truncation, HAL NISSLEY, *I.B.M., 2925 Euclid Avenue, Cleveland, Ohio, 44115*

The purpose of this paper is two-fold: (1) To explore the possibility of real-time statistical quality control plan development on a real-time basis instead of a static use of MIL standards and other orthodox techniques; (2) To research the truncation effects on Wald's Sequential Sampling Plans and study respective α and β shifts. This paper is written for mathematical statisticians who do sampling plan design for quality control.

B4l. An Experiment with a Methodology for System Comparison and Selection, P. R. FATIANOW, *General Electric/ASD, Daytona Beach, Florida.*

This paper presents selected (unclassified) results obtained in an Operations Research Study concerned with the problem of obtaining a quantitative, practical measure of system effectiveness or "value" needed for efficient comparison between and selection from a relatively large number of alternatives. The problem is defined and a solution is presented allowing "value" of a system to be estimated. The method employs the idea of so-called "indifference" or "trade-off" graphs. Data required for the construction of these curves are derived from individuals, qualified by experience with the system and its uses to render value judgements on the relative worth of relevant variables defining the system. The problem of selecting variables needed for system definition is briefly discussed and a solution is offered.

The nature and set-up of an experiment using these methods are described. Experimental results from this application are given together with an appropriate statistical test supporting the theory underlying the methodology.

B. 5. Contributed Papers on Problems and Methods of Marketing

Location: PARLOR B

Chairman: CHARLES K. RAMOND, *Advertising Research Foundation, New York, New York*

B5a. Monte Carlo Analysis of Consumer Behavior in Product Tests, RALPH L. DAY, *The Pennsylvania State University, University Park, Pennsylvania, 16802*

When approximately the same number of consumers prefer each of two products samples in paired comparison tests, does this mean: (a) there is no difference between the samples; (b) consumers can recognize differences but are not influenced by them; or (c) there are significant differences and consumers are influenced by them but these differences offset each other in such a way that a simple tie has occurred (which could be broken by any significant change in either sample)? The foregoing illustrates the kind of problem which is encountered in analyzing the results of product tests. Utilizing a model of preference structure and Monte Carlo simulation techniques, results of a large number of field product tests were simulated. The shapes of preference distributions, characteristics of products, and levels of sensitivity to differences were systematically varied in order to study their effects on product choice. The results suggest some useful guidelines for both the design and analysis of field product tests.

B5b. Introduction of a New Brand in a Highly Competitive Consumer Product Market: Problems, Measurement of the Impact, and Testing of the Managerial Hypothesis, YOSHIRO KURATANI, *Case Institute of Technology, Cleveland 6, Ohio.*

A new brand is often introduced by the company which has already been marketing a well established brand(s), in order to further increase its market share in the industry, increase its net earnings, or utilize its excess capacity, or some combination of these. Whatever motive the company may have, the performance of the newly introduced brand must be measured by appropriately quantified criterion function. This paper reports on the recent study conducted by the author concerning the interaction between two brands of a typical consumer product, including a test of the hypothesis that the new brand competes with the well established brand at the beginning few years of introduction but that the former, after the initial "introductory" period, enhances the sales of the latter for reasons such as strengthening of the corporate image, etc.

B5c. Improving the Accuracy of Market Share Prediction Under Conditions of Innovation: Practical and Theoretical Considerations in the Application of a Modified Markovian Model, RAFAEL B. CRUZ, *Merle Thomas Corporation, Houston, Texas, 77036* and J. O. EASTLACK, JR., *Bristol Myers Company, New York, New York.*

Because of the brand switching marketing patterns of most consumer products, the results obtained by a single consumer survey do not represent the steady state of the market, and it is necessary to take a dynamic approach to arrive as its stable distribution.. Although the theory of Markov Chain Analysis is quite old, the application reported here is entirely new, and powerful enough to be seriously considered by consumer market researchers. To date Markov Analysis has only been applied to the special case of stabilized markets, whereas its true power lies in its predictive application to markets in motion. Our modified Markovian model assumes unlimited time cells and time-dependent transition probabilities, since brand choice itself involves a cumulative preference learning process. We also introduce the concept of market control weighing at the individual respondent level. A time-dependent weighing process is used to develop a fourth order Markovian model and to arrive at a maximum likelihood estimator matrix for applying a first order Markov Chain. The use of this matrix as a two-person game model to develop optimum advertising strategies and a method for determining the relative degree of stability of the market are also shown.

B5d. A Dynamic Model for Competitive Marketing in Coupled Markets, MELVIN F. SHAKUN, *Rutgers—The State University, New Brunswick, New Jersey.*

A dynamic model is developed for competitive marketing situations involving products whose markets are coupled. By coupling it is meant that advertising dollars spent in generating sales for one product have an influence on the sales of another product. An idealized example of such a situation might be the case of two automobile manufacturers each of whom sells a low-priced and a high-priced car. A game-theory approach is taken, and noncooperative equilibrium solutions for advertising expenditures are developed. Effectiveness is measured by discounted future profits. Various aspects of model building for coupled markets are discussed. The present dynamic model extends previous work by the author on a static model for coupled markets.

B5e. A Biometric Model of Advertising, FEDERICO FRISCHKNECHT, *University of Buenos Aires, Buenos Aires, Argentina.*

In order to use LP to optimize an advertising schedule the first problem is to define a common measure of noting as a function of advertisement format and media audiences. Operational definitions of media-audience, advertising-space-audience, media-space exposure and advertisement noting are made in terms of probabilities referred to the population of the market segment considered as a marketing target. For a single medium the advertisement-noting probability is defined by means of a linear combination of media-audience product-detection and format probabilities. The advertisement-noting combination (reach)probability is the total probability for the different media. As media probabilities are conditional, the usual biometric distinction is applicable as studied by Spurgeon (rates versus probabilities (Karup (pure or absolute versus partial or relative probabilities) and others. The total advertisement-noting probabilities are simple but non linear combinations of the individual media probabilities. Such measure is useful to evaluate or simulate an advertising schedule but is not enough for the LP model. For that purpose the weights have to be defined in terms of independent or relative probabilities for each medium. A theorem due to Karup makes the conversion form relative to absolute feasible. The new calculated probabilities are no longer conditional, hence additive and therefore an addequate weight for LP formulation. The total probability is adequate for posttesting by means of a statistical sample of the pertinent market segment. The error distribution of this total probability is a measure of the stability of the model.

B5f. An Operational Theory for Marketing Differentiated Products, ROBERT C. HAIN, *Corning Glass Works, Corning, New York,* and S. S. SENGUPTA, *University of Pennsylvania, Philadelphia, Pennsylvania.*

The purpose of this paper is to develop a theory of strategic action for firms competing in an environment where there are a few firms selling a differentiated product. The theory is operational, that is, it depends exclusively on data available to a firm, not on subjective attitudes. An essential feature is a recognition of the stochastic nature of the sales process. This is embodied in the development of a probability model of sales from a detailed specification of the environmental and institutional factors affecting the firm.

Two models are considered. The static model hypothesizes that sales depend on the levels of price and unit selling expense; while, the dynamic model hypothesizes that sales respond to changes in these variables. These models are applied to several objectives, and strategies for obtaining these objectives are developed.

The basic probability model of sales has been verified with data generated by a process that simulates firms competing in the relevant environment. Some statistical summaries of the behavior of sales and profit are also presented.

B5g. Effect of Company Objectives and Marketing Environment on Optimum Proposal Expenditures for a Government Contractor, EVERETT J. DANIELS, *Lockheed-California Company, Burbank, California.*

Aerospace contractors win government contracts through the submittal of proposals. The quality of the proposal is bound to be affected by the amount of effort which has gone into it. The award of the contract will, in turn, be influenced by proposal quality, but will also reflect some consideration for factors not controllable by the company. The company must allocate its resources in ignorance of the weight assigned by the evaluator to these uncontrollable factors, but with some statistical knowledge of their history. Quantitative relationships are developed in the paper for optimum effort allocations under differing statistical uncertainty distributions and under different company objectives.

B5h. Imperfect Monitoring of a Markov Source with Associated Costs, ALVIN W. DRAKE, *Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139*

A potential customer is modelled by a two-state Markov process. We wish to monitor the actual source state, but this cannot be done economically. At no cost, we may observe a noisy indicator of his present state. The indicator is considered to be a discrete, noisy, memoryless channel for which the actual source states are the channel input letters. At a fixed cost; we may buy perfect information about the present source state. Other costs are associated with correct and incorrect decisions based on our estimate of the source state after each possible transition time. The observer wishes to apply his knowledge of the source dependencies to determine an optimal monitoring policy. A dynamic programming formulation is used to obtain the optimal monitoring policy. Certain limiting properties are obtained in terms of the steady-state statistics of the observer's "state of knowledge" variable. Other applications are indicated for the theory of monitoring a Markov source through a noisy channel.

B5i. Improving Advertising Quality—An Analytical Approach, IRVIN GROSS, *Scott Paper Company, Philadelphia, Pennsylvania, 19113*

Most O.R. activity in Advertising has centered on the effects of quantity (dollars, impressions, etc.). This paper attacks the problem of quality. With an estimate of the probability distribution of the quality (i.e. sales effectiveness) of ads that are likely to be produced, the paper attempts to find the optimal number of alternative ads it is economic to generate and test in order to choose one for running. The results seem to indicate that a greater expenditure on advertising generation and testing might be a very profitable investment. In addition, there are some implications about the fundamental agency-company relationship.

B5j. Variance Considerations in Operations Research Design, ELI S. MARKS, *Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania.*

Most OR solutions, while recognizing stochastic processes, aim at a solution based on an expected value. Variance can be treated in one of 3 ways: (1) ignoring it; attempting to reduce or eliminate it (2) non-statistically or (3) statistically. Approach (1) has great advantages of convenience. It may well, however, lead to a solution where the "expected gain" ignoring variance is less than the standard deviation of the gain. An illustration will be presented in which the "expected gain" allowing for variance is actually a loss. In approaches (2) and (3), it is frequently important to take into account different levels of variation. For example, many models of consumer choice lay emphasis upon the factors which cause variation in the choice of a particular individual and (more or less) ignore *between* individual variation. If it possible to tailor decisions to the individual choice, it is quite appropriate to ignore *between* individual variation and concentrate on *individual choice* functions. But *most* decisions in the *real* world require setting a uniform policy for all individuals. For example, the decision may be between (a) reducing prices 10¢ per unit, (b) spending 10¢ more per unit to improve service or quality, (c) spending 10¢ more per unit on advertising (or "propaganda"). We must, however, make the *same* decision for all customers—i.e., we can't reduce price for A, improve service for B, and give C a better "sales pitch" although the *optimum* policies for A, B, and C respectively may well be to do precisely that. Under such circumstances to make a *perfect* determination of the optimum for each of a sample of persons may be of little value, if the variation among persons is large and the sample is small.

B. 6. Contributed Papers on Problems and Techniques of Inventory Control

Location: BALLROOM EAST

Chairman: EDWARD H. BOWMAN, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

B6a. An Approximate Solution for a Multi-echelon Inventory System, R. L. LAYTON, *Bell Telephone Laboratories, Holmdel, New Jersey.*

This paper involves the determination of an approximate ordering policy for a multiple installation inventory system, or more specifically, a multiechelon inventory system. A three installation arrangement is considered and a model is developed making several of the standard assumptions ued for dynamic systems. A cost function $C_n(X_1, X_2, X_3)$ is defined recursively for installations 1, 2 and 3 in terms of the respective inventories X_1, X_2, X_3. $C_n(X_1, X_2, X_3)$ represents the minimum expected value of the discounted system costs if there are n periods remaining and an optimal procedure is followed throughout. The problem of determining optimal ordering policies is a dynamic programming problem which is theoretically solvable. The difficulty, however, is of a computational nature since at present no feasible means of computing the policies exist. This paper develops approximate ordering policies which are obtained as a result of bounding the original cost function $C_n(X_1, X_2, X_3)$ by a sum of three functions, each of a single variable. The bounding functions include the cost functions for the well known single installation problem and the same numbers that characterize the single installation policies also characterize the policies developed in this paper. Several computations were performed and the results indicate that the model is good for a small number of periods. Behavior for large n needs further consideration.

B6b. Decision Aid for Spare Parts Provisioning, L. R. GUTSTADT, *North American Aviation, Space and Information Systems Division, 12214 Lakewood Blvd., Downey, California.*

This paper presents the results of a team effort to develop a tool used as a decision aid in determining quantities of spares to be ordered. The analytical solution is of the probabilistic closed form type with an open ended result since one set of input data results in several sets of output data. This output information is then used by the decision maker when determining what quantities to order. The selection is based on the input confidence level required of the data plus the required availability and costs of spares. Order quantities are calculated from equations derived by considering an inventory control diagram; the parts flow process; burn in, wearout and random failure modes; and the costs due to normal provisioning or having a shortage or an overage of spare parts. The computer program is described, several applications are shown in regards to its usage and the results of a sensitivity analysis are given.

B6c. Bayesian Determination of the Reorder Point of a Slow Moving Item, EDWARD A. SILVER, *Arthur D. Little, Ind., 35 Acorn Park, Cambridge 40, Massachusetts.*

Consider an inventory item for which the procurement (or production setup) lead time is non-zero. One of the commonly used methods of determining the reorder point of such an item is to specify a desired service level (fraction of demand that is to be instantaneously satisfied) and then select the reorder level that will provide such service. However, such an approach has assumed that the probability distribution of demand during the lead time is exactly known. In many inventory situations this assumption is not justified, particularly in the case of a slow moving item with limited available sales history. For such a situation this paper explores the use of a Bayesian approach to selecting a reorder point. A discrete distribution of demand in the lead time is assumed; however, the probabilities of the various demand sizes are not assumed exactly known, rather a multi-dimensional Beta distribution is placed over them. A discussion of how to select the prior parameters of this Beta distribution is included. Finally, a simple expression is developed for the reorder point as a function of the service level, the aforementioned prior parameters and any additional sales data.

B6d. Practical Aspects of Economic Order Quantities, Irving Katz, *Operations Analysis Office, HQ Air Force Logistics Command, Dayton, Ohio.*

The application of Economic Order Quantity (EOQ) management theory in the real world suffers from its inattention to many problems, two of which have been attacked in a recent AFLC study. First, the theory assumes that demand rates are stationary distributions. The new study searches for trends and abrupt changes in demand, and translates its findings for the standard EOQ formula. Second, by making Safety Level calculations independent of the EOQ formula, the theory assumes that the quantity procured in each cycle is not related to support effectiveness. This is not valid, because the percentage of time in which there is an exposure to shortages is affected by the frequency of procurement. Therefore the new study has introduced improved rationing procedures and an initial effort to improve Safety Levels. In the process, several special purpose estimates of the demand rates are used, in contrast with typical multi-purpose application of a single estimate. A computer simulation of some of these procedures reveals that they simultaneously reduce costs and increase support effectiveness.

B6e. Improved Control of an Operating Distribution System, James P. Morris and Robert Cleveland, *Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland,* and Joseph Glaser, *American Airlines, New York, New York.*

A case study of an operating assembly and distribution system is presented. Six subcontracted components are assembled in fixed ratios into modules at 81 assembly and distribution points (ADPs). Although the total number of modules to be distributed from each ADP is known, the rate of distribution fluctuates. Three major problems were encountered: in many cases, component inventories at individual ADPs were not in the specified modular ratio; procurement and production activities had to be scheduled to satisfy the fluctuating demand; high transportation costs. Scheduling problems were solved by extending an existing PERT/CPM system into the procurement/production cycle. Transportation costs were reduced by using existing computer programs of the Transportation Model. A special model was designed to solve the inventory problem; salient features of the model were its consideration of consumer priorities, and its susceptibility to automatic data processing. The proferred solution did not purport to optimize system operation, but it attacked the most pressing problems, and could be implemented with relative ease through the coordinated use of several well-understood concepts.

B6f. An Allowance List Decision Rule on METRI, Bernard N. Samers, *Clark, Cooper, Field & Wohl, Inc., 123 High Ridge Road, Stamford, Connecticut.*

The lowest inventory echelon in the Navy (the ship) is controlled by means of an allowance list which specifies the inventory of each spare part to be carried. The allowance list reorder is on a one for one basis. The decision problem in selecting an allowance list, then, is specifically the range (which) and depth (number) of spares to be carried. The technique described, develops a decision rule which takes into account the cost, reliability and military essentiality of spare parts. "Readiness" of the ship is the objective function which is maximized for a given investment cost constraint. The "readiness" function is developed using the METRI (Military Essentiality Through Readiness Indices) technique. Basic to this concept is a simulated structural model of the ship through which the effect of particular spare parts (on the list) to the "readiness" of the ship is evaluated, based on their contribution to improved reliability. The technique, in addition to producing a particular list, can be used to evaluate the readiness and cost of any actual (or proposed) list.

B6g. A System for Evaluating Purchase Strategies in Resale Industries, James H. Heeremans, *Arthur Anderson & Co., 294 Washington St., Boston 8, Massachusetts.*

The range of gross profit potential for distributor or jobber operations is normally specified by the original manufacturer through publication and wide dissemination of purchase and resale price schedules. In many industries these price schedules contain numerous quantity discount levels for both the distributor (when he makes purchases from the manufacturer) and the retailer or ultimate customer (when the distributor consummates a resale). The actual gross profit achieved by the distributor on any single transaction fluctuates widely depending upon the relationship between his original purchase quantity from the manufacturer and the size of the resale order to his customer. This paper presents a practical system for identifying the purchase quantity the distributor should select to maximize the gross profit from his operations including inventory carrying cost considerations. The system is based on the formulation of probability distributions describing customer demand patterns in terms of the distribution of individual resale order quantities as well as total demand for an item. These demand patterns are then applied to buy-sell gross profit matrices and optimal purchase strategies for each item in the distributor's line are formulated.

B6h. A New Approach to Inventory Stockout Penalty Costs, Benjamin L. Schwartz, *Data Dynamics, Inc., 305 Webster St., Monterey, California.*

In classical inventory models, penalty costs are often included. These occur whenever the demand for a commodity temporarily exceeds the supply. They are assessed linearly; that is, so many dollars for each unit of shortage. The rationale often given is that the occurence of unsatisfied demand will cost the firm in customer goodwill. But it is universally acknowledged that the actual measurement of the penalty coefficient is exceedingly difficult. An alternate approach to stockout penalties is given in this paper. The central idea is that a customer may change his ordering pattern as a result of encountering an outage. The frequency with which he places orders or the average order size of orders may be reduced. Thus, when a shortage occurs, the firm may experience no immediate penalty, but its demand pattern in the future will be perturbed, and it will see a penalty in the form of some loss of potential future sales. Several models using this idea are developed, and optimal stock management policies for the firm obtained. The relationship between such models and the classical ones is also obtained.

B6i. The Weibull Distribution as an Inventory Control Application, JOSEPH W. TIMPE and JAGDISH N. PATEL, *Microswitch Division of Honeywell, Inc., Chicago and Spring Streets, Freeport, Illinois.*

The problem of creating a filter to eliminate large, extraneous customer orders from a demand distribution has continually plagued computer oriented forecasting and inventory control systems. These non-repetitive orders increase stock balances while providing little or no return on the additional inventory investment. A computer program utilizing the Weibull distribution can be used to replicate the actual demand distribution and isolate the extraneous customer orders. This technique has the advantage that it is a family of curves which can represent distributions ranging in form from exponential through normal, dependent upon the actual sample value. Heretofore restricted mainly to reliability testing and quality control applications, the Weibull distribution has definite merit in demand distribution analysis. By calculating the Weibull of best fit for each product and analyzing percentage points on the upper tail, the quantity beyond which all customer orders should be job shopped can be determined. Simulation techniques involving forecasting, lot size reordering, and customer order classification can be used to present management with alternative quantity cutoff points. Decisions concerning the most feasible quantity cutoff can be based upon the mix between job shop and stock replenishment work orders, workload fluctuation created, inventory levels maintained, average shipping delay to customers, and back orders generated.

B6j. Optimal Procurement Decisions for Spare Aircraft Components, D. HOEKSTRA, R. L. DEEMER, and S. GADJALO, *Frankford Arsenal, Building 109-3, Bridge and Tacony Streets, Philadelphia, Pennsylvania.*

There has recently been an intensified search, initiated by the Assistant Secretary of Defense (Installations and Logistics) in response to Congressional criticism, for improved management techniques in the area of aircraft spares. This paper discusses a decision model for the procurement of major aircraft components such as engines, transmissions, gearboxes, etc., which was developed for the U. S. Army Aviation Materiel Command. Important factors in deciding how many items of each component should be carried in support of a given aircraft type are: the performance characteristics of the supply and maintenance system, the failure characteristics of the different components, the number and geographical dispersion of the aircraft population to be supported, and the relative costs of components and aircraft. A two-level circular inventory model was developed earlier which is used to find the relationship between the number of spares and the "optimal" supply performance for a particular component. It is shown how these inventory level/supply performance relationships can be approximated with exponential functions. It is then possible to derive, analytically, the combination of spares levels for the different components which maximizes the availability and consequently the operational readiness of the supported aircraft population given a certain total spares procurement budget. In principle, an "optimal" procurement budget can be formulated by attaching a cost to each (average) aircraft down for lack of parts.

THURSDAY EVENING MAY 6, 1965

(5:30–7:00)

Cocktail Hour & Mixer

Location: BALLROOM WEST

(7:30)

Banquet

Location: BALLROOM EAST

Retiring Presidential Address

GEORGE E. KIMBALL, *Vice President, Arthur D. Little, Inc.*

Introduced by

PHILIP M. MORSE, *Massachusetts Institute of Technology*

FRIDAY MORNING, MAY 7, 1965 SESSION C

(9:00–12:00)

C. 1. The Structure of Investment Decisions

Location: GEORGIAN ROOM

Chairman: GEORGE R. MURRAY, *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

C1a. Practical Difficulties in Attacking the Investment Problem, HERBERT AYRES, *Morgan Guarantee Trust Company, New York, New York.*

While it is true that recent decades have brought us to the point where it appears possible to treat the investment decision under uncertainty, the way is neither easy nor clear. There are a variety of difficulties. Very little is known about investor preference. In spite of the expected value of utility theory very little experimental work has been done, and there is some question about experimental techniques for ferreting out decision makers' indifferences Almost all appropriate models require estimation of future events which are uncertain. Few of these estimates have been made historically and recorded. As a result it is difficult, if not impossible, to validate a particular technique or theory using historical information. Furthermore, at least with respect to stock market prices, experiments must extend over years to develop confidence that a particular tool represents an improvement on present practice. Additionally, the mathematical treatment of diversification is so cumbersome in its pure form that approximations must be sought. Finally, the very nature of the stochastic processes of the market place are not known. As a consequence, quantitative statements about the confidence of projected values are questionable at best. As is usually the case in operations research, the essence of the problem is to pick a set of short cuts and approximations which allow operational feasibility without sacrificing accuracy.

Clb. Mathematical Models in Capital Budgeting: Opportunities and Limitations, CHARLES CHRISTENSON, *Harvard Business School, Soldiers Field Road, Boston, Massachusetts.*

There has been increasing interest in the application of mathematical models or techniques in capital budgeting. In addition to variants of the discounted cash flow approach, recent years have seen a growing literature on models dealing with such important problems as interdependent investments (e g , programming models) and uncertainty (e.g., simulation models). This paper will discuss the rôle these sophisticated techniques have to play in the overall capital budgeting program of a firm. It will emphasize the limitations as well as the opportunities, pointing out circumstances under which a management would be well-advised to reject a purported "optimum" generated by such techniques.

Clc. The Effect of Accounting Conventions on Business Investment Standards, JOHN F. MAGEE, *Vice President, Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

Within most sizable corporations, the problem of investment management is one of directing the flow of funds from operating revenue or from outside sources into expenditures that will stimulate adequate revenue in the long run. The distinctive characteristic of an investment expenditure is that the resulting revenues will be spread over a measurable time in the future.

A number of systems are in use today, usually several within a given firm, to manage investment decisions of various types. These are characteristically not designed to deal with the total investment in a given venture but tend to be fragmented and heavily influenced by accounting conventions. Accounting conventions in the tradition of conservatism and from a search for historical consistency have lagged the shift in the character of business investment and in fact do not readily permit the identification of investment from the accounts of the firm.

An attempt will be made to classify investment management systems and show how accounting conventions have affected the design and operation of these systems.

Cld. The Nature of Risk in Investment Decisions, DAVID B. HERTZ, *McKinsey & Company, New York, New York.*

Investment decisions are subject to a variety of uncertainties that, when combined with the stake at issue, determine the degree of risk involved. It is important to recognize that the risk perceived by the individual taking part in an institutional decision-making process may be quite different from the risk for the institution as a whole, or any of its parts. The nature of the risk is, in part, described by individual utility functions. Beyond the utility function, which may have meaning when the uncertainties and stakes are well known, are the risks associated with estimates of these elements of the investment decision. It is one thing to know the odds on a throw of a pair of dice; quite another to estimate, among other things, the number of dice, the number of sides of each, and what is on those sides. In addition, the usual investment decision has an uncertain stake. For these reasons, knowledge of risk is critical to successful decision making; for these same reasons, it is more often ignored or heuristically explored than rigorously examined. Methods of exploring risk in various kinds of investment decisions will be described and an approach to clarifying the relationships among uncertainty of stake and uncertainty of outcome discussed.

C1e. Problem Areas in Securities Analysis and Portfolio Management, L. G. PECK, *Goldman, Sachs and Co., 20 Broad Street, New York 5, New York.*

The paper stresses the advisability of understanding in detail the methods and techniques which are currently used by successful analysts and financial managers before attempting to build sweeping models as a basis of long-range strategies. The areas to be investigated fall into three convenient classes:

Methods of projection, strategy and timing of trading, and measurement of performance.

In the first category, the importance of earnings projections is brought out and suggestions are made for refinements and modifications of existing techniques. In the second category, an example of trading stragegy which is widely used for "balanced" portfolios is discussed in detail. What appears on the surface to be an inferior method of handling portfolios, turns out on closer inspection to have unsuspected advantages. A mathematical treatment, based on a simplified model, suggests that a full scale simulation should be carried out before making definitive recommendations. The last category is discussed only far enough to make clear the need for a variety of techniques of measurement corresponding to the variety of tasks in securities analysis and the variety of objectives in portfolio management.

C. 2. Stochastic Models in Marketing

Location: STANBRO HALL

Chairman: LAWRENCE FRIEDMAN, *Operations Research Director, M and M Candies, Hackettstown, New Jersey*

C2a. The Use of Stochastic Market Models in the Analysis of Consumer Panel Data, JEROME D. HERNITER, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

The principal stochastic models in use for the analysis of consumer behavior are the semi-Markovian model and the linear learning model. Both models are being used to analyze market changes as reflected in consumer panel data.

The basic structure of the linear learning model is that each consumer has a set of parameters at every point in time. These parameters can be interpreted as the probability the individual will purchase each brand on his next purchase occasion. After a purchase of a particular brand, all of the parameters are modified by means of linear transformations. We assume in the semi-Markov model that each consumer can be characterized by a Markovian transition matrix, a time between purchase distribution and a purchase size distribution. In its simplest form the transition matrix is assumed to be the same for all consumers.

While both models provide useful guides for the analyses and interpretation of panel data, both models are demonstrably incorrect. To explain the data more completely it is necessary, in the semi-Markovian model, to assume distributions of the transition matrices over the population and to assume distributions of the parameters in the linear learning model. These extensions yield more appropriate models of consumer behavior.

Examples drawn from the Chicago Tribune panel data will be used to demonstrate the strengths and weaknesses of both models. Further extension of the models shall also be discussed.

C2b. New Product Introduction—A Perturbation in the Market Place, BENJAMIN LIPSTEIN, *Benton & Bowles, Inc., New York, New York.*

A new product introduction in test markets causes a disruption of existing attitudes and buying patterns in the product category. These disturbances are observable in the attitude and buying matrices. A stochastic model is suggested which describes the dislocation that occurs in the market place. The ensuing attitude and purchase matrices which are Markovian are also non-stationary. An analytical method is provided for handling these non-stationary chains under restricted conditions. Some mathematical criteria are given which indicate when the market will return to normal and what the share achievement of the new brand is likely to be under stability conditions.

C2c. A Model of Adaptive Control of Promotional Spending, JOHN D. C. LITTLE, *Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A simple model of adaptive control of promotional spending when sales response changes with time is analyzed and then illustrated by simulation. In the model, company sales (and therefore profits) are a function of a promotional spending rate x. Sales response to x changes as a result of changes in a parameter of the sales response function. Information about the parameter is collected each time period by performing an experiment. On the basis of present and past information, the value of x is picked to maximize expected profit in the next period. The size of the experiment is chosen to minimize the losses from imperfect information and from performing the experiment.

C2d. Order and Homogeneity of Family-Specific Markov Chains for Coffee Brand Choice, WILLIAM F. MASSY, *Graduate School of Business, Stanford University, Stanford, California.*

Most empirical work on Markov processes for brand choice has been based on aggregative data. This paper explores the validity of the crucial assumption that underlies such analyses: i.e., that all the families in the sample follow a Markov process with the same or similar transition probability matrices. This assumption is required if the pooled sample transition counts are to be sufficient statistics for the process, and for the application of the Anderson and Goodman hypothesis tests on Markov chains. If all families do not follow the same probability law the aggregative process is not usually well defined, and the usual method for calculating "transition probabilities" will produce misleading results because of the phenomenon known as contagion.

Results, based on seven years of coffee purchasing data for a subsample of families in the Chicago Tribune Consumer Panel are reported. A brand switching process based on the family's first and second brands, with all other brands treated as a group, was defined for each member of the sample. Each family's switching process was tested for stationarity over the seven years covered by the data, and a separate transition probability matrix was calculated for all those who met this criterion. Then the order of each of the family-specific matrices and their homogeneity among various subgroups of the sample were tested. It appears that there is a good deal of diversity among families' switching processes, and that some of them are of zero rather than first order.

C2e. New Dimensional Analysis of Brand Switching, ALFRED KUEHN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania,* and ALBERT C. ROHLOFF, *Lever Brothers Company, New York, New York.*

Studies of brand switching have generally focused upon the sequences of consumers' purchases. For the most part, such factors as quantity purchased, time between buying occasions, the existence of "deals," and the size, model, color or flavor of the item purchased are not recognized explicitly in the analysis. This paper attempts to demonstrate the importance of these variables in the brand choice process and outline some ways in which they might be incorporated into analyses of consumer behavior.

Brand switching studies which side step the above attributes of individual purchases neglect some of the most important dimensions of consumer choice. A consumer's interest in an ultimate choice of a specific brand is frequently influenced by such differentiating attributes. Consequently, it is not surprising that the measurement of the effects of these variables can be of great importance to marketing management in formulating product policy and in the planning and implementation of dealing activities and advertising strategy.

C. 3. Contributed Papers on OR on Social Problems

Location: PARLOR A

Chairman: HARRY ELLIS, *Harbridge House, Boston, Massachusetts.*

C3a. Optimal Procedure for An N-State Testing and Learning Process, W. KARUSH and R. E. DEAR, *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California, 90406.*

The multi-stage decision process considered arises in learning theory and involves the state, "conditioned" or "unconditioned," of a system (learner) relative to each of n items. The state is unobservable; observable is the response, correct or incorrect, to an item presentation. In each trial of an N trial process (experiment), the decision-maker (experimenter) selects an item for presentation based upon past performance. A system conditioned to item i always responds correctly when presented with i; if unconditoned, it responds correctly with probability γ. Each trial includes corrective action permitting change of states; transition from unconditioned to conditioned state occurs with probability θ during a trial (the conditioned state is permanent). Given initial probabilities $\lambda_1, \lambda_2, \cdots, \lambda_n$ of being conditioned to the respective n items, the effectiveness of a strategy of item presentation in improving conditioning is an expected loss depending upon the terminal conditioning probabilities. We prove the following is optimal: in any trial, present an item whose current conditioning probability is least. We also show this is an optimal strategy independent of θ (θ may vary with the system in practice) when the initial λ_i are all zero.

C3b. Heuristic Games for Secondary Schools, Clark C. Abt, *Abt Associates, 14 Concord Lane, Cambridge, Massachusetts.*

The situational variables and their dynamic relations in several typical social science problems encountered in pre-college formal eductaion are identified and compared to the similar characteristics of some formal games. A non-mathematical theory of educational game design is formulated, including tradeoffs between realism and operability, player involvement and analytic depth, and substantive concentration and comprehensiveness. Four operational educational games are described: *Empire,* an economic game illustrating the mercantile conflicts of interest between England and the American Colonies in 1730–1770; *Steam,* a game illustrating the concatenation of economic pressures and technological advances leading to Newcomen and Watt's steam engines from 1700–1780; *Manchester,* a political-economic-technological game illustrating the development of the machine factory curing the early industrial revolution; and *Grand Strategy,* a military-political-economic game of contemporary global cold war conflict. The educational advantages and limitations of such games are discussed, as well as future implementation of more sophisticated games integrating human player activity with computer operation of complex data bases.

C3c. A Model for the Design of Prepaid Dental Plans, David A. Schrady and Burton V. Dean, *Case Institute of Technology, Cleveland, Ohio, 44106.*

The purpose of this paper is to present a basic model to be used in optimizing the design of prepaid dental plans. A mathematical model is developed to relate the characteristics of the plan and of the eligible members to the amount of unsatisfied need and the cost of operations. Those plan characteristics that can be controlled by the plan designer are the services to be offered and the financial and organizational structures. The socio-economic characteristics and previous dental history of the eligible members are considered to be beyond the control of the designer.

The basic model parameters for each service considered for possible inclusion in the plan are the amount by which a person's oral health is enhanced when the service is received, the percentage of eligible plan members that will require the service, and the average cost of the service.

The model further requires quantitative information on the effects of the plan characteristics on the percentage of plan members that will receive a particular service from the plan when they require it. A dynamic programming procedure is presented for solving the model in the most important case of selection of services to be provided.

C3d. Operations Research and the Study of Public Policy Problems: A Specific Case,

ERIK A R. HALDANE, *Department of Economic Affairs, Organization of American States, Pan American Union, 1725 "I" Street, N.W., Room 1009, Washington, D C., 20006.*

In order to focus on methodological and operational problems connected with attempting to apply operations research conceptualizations and techniques to the determination of public policy, the author's effort to study air, water, and soil pollution from a broad systems point of view will be examined. The exposition and assessment will include problems and solutions, makeshift or otherwise, with respect to the establishing of objectives, effects, and boundaries, as well as difficulties with conceptualization relative to different levels of aggregation, and with fitting the existing data base to the conceptual handles. Computer uses and limitations in this context will be explored, and an effort will be made to outline the possible scope of cost-benefit analysis.

C3e. Investment Decisions in Newly Developing Countries,

MORRIS J. SOLOMON, *U.S. Bureau of the Census, Washington 25, D. C.*

The newly developing countries are characterized by pitifully small amounts of capital available for investment. Despite the critical importance of investment decisions, the framework for making and implementing such decisions has been poor, from the point of view of attaining rapid growth. The writer has synthesized the thinking of engineers, economists, and operations researchers into an operational framework that can be taught readily, and is appropriate for economies that place a high premium on economic growth. This framework has been taught to foreign graduate students in economics, government administrators in Turkey, project personnel in Venezuela, and planning personnel of the five Central American Republics of the Central American Common Market. Experience to data indicates that such a framework can be taught readily, but that the chief limiting factors in application are the rules of the game prescribed by political authorities, and the available mechanisms for implementation. This suggests that if rapid progress is to be made, far more effective ways must be found for communicating with the political authorities in question.

C3f. Operations Research: Can it Implement, or Create, Social Values?,

SAMUEL E. GLUCK, *Division of Business, Hofstra University, Hampstead, L. I., New York.*

There has been growing success in applying O.R. concepts and techniques to societal problems. Industrial allocation and distribution models transferred to the management of hospitals have matured into proposals for national health programs.

Current and long-range planning of (e.g.), water supply utilization have likewise evolved from more restricted applications. And, the path from-firm-to-industry-to-macroeconomy has contributed greatly to the survival potential of underdeveloped nations. In each case, O.R. has functioned within an already established socio-*philosophical* framework: i.e., health, welfare, conservation, security and abundance, and concern for future generations are part of the ethos and the ethic of our society. *Given* these values, we work to consummate them. But we also know that O.R. is used with equal effectiveness by societies opposed to our values. Further, the method of analysis (O.R. included) alters the researcher's *interpretation* of a problem. Does it change its actual configuration as well? This paper seeks to clarify these and other questions. What is a true 'social problem'? How is it recognized? Are there "qualitative" as well as quantitative criteria? Does O.R.—*should* O.R.—attempt to *create* social values?

C3g. Predicting Air Pollution Levels, RONALD W. WOLFF, *Department of Industrial Engineering, University of California, Berkeley, California.*

A model for predicting the air pollution concentration and pollutant transport in a metropolitan area is presented. Using meterological and emission data as inputs, computer simulation is used to generate predicted (model) pollutant levels at various times and locations on pre-selected days. The model is evaluated by comparing predicted with measured levels at the same times and locations.

C3h. Game Theory Applications to Service Site Selection, WILLIAM L. MOOG and NEWTON DIKOFF, *Social Security Administration, Department of Health, Education and Welfare, Washington, D. C.*

This effort deals with the problem of developing various criteria for selecting a number (n_s) of service sites from a group of proposed ones (n_p) where n_p is greater than n_s. No consistently quantifiable criteria exist at the present time. Measures of effectiveness for each criterion include cost ($), distance (miles), system load (in defined units), population (by pertinent cohorts), and economic factors. The approach used here involves the establishment of criteria, development of measures of effectiveness, weighting the pertinent measures, and analyzing these weights via game theory techniques. The basic (and typical) problem in this approach is in the reduction of the game to a soluble form, utilizing methods of dominance and analyzing the effects of this by varying the assigned weights. An actual system is described here, and the application of this approach is evaluated.

C3i. A Model for the Prediction of Demand for Nursing Service, WARREN H. THOMAS, *Department of Industrial Engineering, State University of New York at Buffalo, Buffalo, New York.*

Because individual patients in a hospital vary considerably in their requirements for nursing service, the total demands for service imposed by all patients within a nursing unit fluctuate widely from day to day. A Markov model is developed whereby a patient's near-future recovery status can be predicted from a knowledge of his current status. Since demand for service is a function of recovery status, it is therefore possible to determine a patient's expected need for service. The total expected demand for a nursing unit would be the aggregate of such anticipated demands from all patients within the unit.

Extensive study of coronary patients was made in which it was found that there are four well identifiable recovery states. By subdividing each of these states into three recovery phases and by the inclusion of an entry and an exit state, it is possible to represent satisfactorily a coronary patient's recovery process.

The total length of stay and the state-to-state transition characteristics of the model correspond well to those of actual patients.

C3j. The Library as an Inventory Problem, RICHARD W. TRUESWELL, *School of Engineering, University of Massachusetts, Amherst, Massachusetts.*

In recent years much interdisciplinary research activity has occurred in research on libraries. Several mechanizations and some automation programs have been started. Circulation control, periodical records, book storage, and book purchasing have had computer applications. In general a closer look is being taken at the library and its operations.

This paper is directed at analysis of the library's holdings as an inventory problem. A considerable amount of data has been collected regarding use of books at the libraries of two nearby colleges. This data has been used to define use rates for the library's holdings. From these rates an attempt has been made to describe an inventory policy as part of a larger semi-automated library system.

This system would have the features of minimum holdings size for local libraries but permit almost immediate determination of system availability of non-core collection books. The core collection would be the holdings at the local library and by design satisfy 99% of current user requirements.

Previous research indicates that the last circulation date for a book may offer an excellent parameter for describing circulation patterns and user requirements. The effect of the subsequent more extensive data on validity of the conclusions of the earlier research will be reported.

C. 4. Contributed Papers on Programming Methods of Operations Research

Location: BALLROOM WEST

Chairman: DAVID F. VOTAW, JR., *The MITRE Corporation, Bedford, Massachusetts.*

C4a. Modular Design, Generalized Inverses and Convex Programming, A. CHARNES, *Northwestern University, Evanston, Illinois,* and M. KIRBY, *Research Analysis Corporation.*

We show that the Modular design problem

$$\text{Minimize } \sum_{i=1}^{m} y_i \sum_{j=1}^{n} z_j , \qquad \text{subject to } y_i z_j \geqq r_{ij}$$

$$y_i , z_j > 0 i = 1, \cdots , m. \qquad j - 1, \cdots , n.$$

can be transformed into a problem of minimizing a separable convex function subject to linear equality constraints and non-negativities. This transformation is effected by using a generalized inverse of the constraint matrix. Moreover the nature of the functional and the constraints of the separable problem are such that a good starting point for its solution can be obtained by solving a particular transportation problem. We discuss several possible methods for solving the separable problem and give the results of our computational experience with these methods. We also show that the Modular design problem can be viewed as a special case of a large class of general engineering design problems which have been discussed in the literature.

C4b. Techniques for Solving Multiple Assignment Problems, HARVEY WOLFE, *Department of Industrial Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania.*

There exists a set of allocation problems such that each individual is permitted to perform an unlimited number of tasks provided that the total time required to perform all tasks is less than a specified time period, usually a workday. This extension of the simple assignment problem has applications in the allocation of nursing tasks to nursing personnel, the allocation of jobs to craftsmen in a job shop, and in many other areas where assignments are of limited duration.

Initial formulation of a model to describe the multiple assignment problem assumes discrete time periods, no overtime and varying effectiveness on the part of the individuals in performing each task. The solution to this model is of practical value only if in integers; however, the magnitude of most real world problems far exceeds the capabilities of currently available integer programming algorithms. Nevertheless, problems of moderate size can be solved using Gomory's integer programming techniques.

An algorithm has been developed which yields the non-integer solution for any size problem very quickly. Using these non-integer results as a first feasible solution to the integer problem, a heuristic algorithm can be considered that makes use of the properties of the model in attaining an improved, although not necessarily optimal, solution. This technique has been used to solve numerous problems exceeding 100 variables. In all cases the solutions effected in this way have been very near, if not at, the true optimum. For practical problems this heuristic approach has proven quite adequate; however, considering the ease with which a good first feasible solution can be found, the possibility of a true optimum solution remains.

C4c. A Resource Allocation Problem, SOCRATES LITSIOS, *Booz, Allen Applied Research, Inc., 4815 Rugby Ave., Bethesda, Maryland.*

Several sequencing problems, which arise in the course of allocating one or more constrained resources to two or more tasks, are investigated. In all problems we are concerned with determining the optimal sequence of tasks and the optimal scheduling of resource usage where the objective is to minimize the time by which all tasks are completed. The following assumptions apply to the first problem considered: (1) A single reusable resource (men, equipment, etc.) is available for allocation where $R(t)$ defines the amount available at time t. (2) n tasks are to be sequenced where each task is defined by a task completion time-resource required curve, i.e., the possibility exists of trading resources used for individual task completion times. (3) No two tasks can be undertaken during an overlapping time period. This problem is solved by a combination of dynamic programming and combinatorial analysis techniques.

In the second problem, the single resource is assumed to be of the nonreusable (fuel, food, etc.) variety and constraint (3) is no longer imposed. It is shown that this problem is a graphical "dual" to the first, and lends itself to being solved by an iterative application of the techniques used in the first problem. Multiple resources are considered in the final group of problems. The above "duality" no longer holds and the general techniques being used only apply to several special cases. Numerical results are provided for the single-resource problems which illustrate that the solution time grows as 2^n, where n is the number of tasks to be sequenced.

C4d. Decomposition Analysis for Multiple Constraint Values and Objective Functions, JOHN S. BONNER, *Bonner and Moore Associates, Inc., Houston, Texas,* JOHN P. BASILE, and HARRY GILDEA, *Management Systems Corporation, Cambridge, Massachusetts.*

This paper describes the application of decomposition techniques in the solution of a large linear programming problem to determine an optimum budget allocation.

The matrix contained approximately 1400 decision variables and 1400 constraint equations. The structure of the matrix was such that it could be partitioned conveniently into 20 sub-problems with about 60 extremal equations, including 16 objective functions.

Eighty-eight cases with different combinations of objective function and right-hand-side vector were run on an IBM 7094. An existing decomposition code was modified to permit automatic sequencing through different objective functions and right-hand-side vectors by means of cards stacked in the on-line reader.

Detailed information on the patch to solution is discussed in terms of the structure of the problem. Computation times are compared for various degrees of relaxation of the extremal constraints. Error checking and reinversion characteristics are discussed.

C4e. A Defense System Budget Allocation Study, HARRY GILDEA, JOHN P. BASILE, and COLLIN W. SCARBOROUGH, *Management Systems Corporation, Cambridge, Massachusetts*

This paper described an analytical cost effectiveness study performed recently for one of the military services. The central problem approached in this study is that of allocating program funds among alternative design and design improvement plans for a number of systems.

Statistical measures of the military effectiveness of each configuration of each system were obtained by computer-aided analysis of actual and estimated performance data. Research and development, procurement and installation cost estimates were also obtained.

Linear programming was employed to determine the best mix of plans to fund within budget, technological and schedule constraints. Because of the large size of the problems relative to existing linear programming codes, it was necessary to employ decomposition techniques. A large number of cases were run to determine the sensitivity of the optimum solution to funding limitations and to alternative statistical measures of effectiveness.

C4f. The Chinese Postman's Problem, JACK EDMONDS, *National Bureau of Standards, Washington, D. C., 20234.*

The problem is to find in a given network a tour which traverses each edge at least once and which has minimum length. First treated by KWAN MEI-KO, "Graphic Programming using odd or even points", translated in *Chinese Math.* 1 (1962), 273–277, it arose "when the author was plotting a diagram for a mailman's route". Quoting D. R. FULKERSON in *Math. Reviews*, v. 28, no. 6 (Dec. 1964), # 5828: "Suppose given a finite, connected graph in which each edge has associated with it a nonnegative number, its "length". This paper considers the interesting problem of adding duplicate edges so that (1) the resulting graph is unicursal, and (2) the total length of duplicated edges is minimal. It is shown that a necessary and sufficient condition for minimality is that the sum of the lengths of duplicated edges in each simple cycle be at most half the length of the cycle. The author describes how this minimality test can be used to construct a solution to the problem. Unfortunately, the construction involves examining all simple cycles to see whether the minimality test is met or not, and this is easier said than done". We present an algorithm which does not involve examining simple cycles. It is "good" in the sense that the amount of work in applying it is at worst moderately algebraic, relative to the size of the graph, rather than exponential. It combines two earlier known algorithms: (1) the well-known "shortest path" algorithm, (2) a recent algorithm for "maximum matching" (Edmonds, NBS Journal of Research, B, v. 69, Jan-March 1965). Maximum matching is, given a graph with a real numerical weight on each edge, to select a set of edges with maximum total weight such that no two edges in the set meet the same node

C4g. Primal-Dual Decomcosition Programming, EARL J. BELL, *Department of Industrial Administration, The University of Connecticut, Storrs, Connecticut.*

A primal-dual method for solving linear programs with a block-angular matrix structure is presented which employs the Decomposition Principle of Dantzig and Wolfe who first studied this structure. Preliminary results indicate that the proposed method is more efficient than the standard decomposition method which uses the two-phase simplex method to solve an equivalent "external program" with a reduced basis size whose coefficients are generated through the solution of linear subprograms. By contrast the proposed method employs a primal-dual method and the coefficients are generated through subprograms with non-linear objectives.

These subprograms involve the maximization of a quotient of two linear functions subject to linear constraints in non-negative variables. Such problems are known as linear-fractional, rational objective, or hyperbolic programs and can be solved as a variant of standard linear programming. Under the conditions imposed by the primal-dual method, special parametric techniques can be employed to take advantage of particular matrix structures, such as the transportation structure, exhibited by the subprograms.

C4h. The NORMA: A Possible Basis for a Theory for the Traveling-Salesman Problem, NORMAN P. SALZ, *Cornell Aeronautical Laboratory, Inc.*

We consider the symmetric traveling salesman problem in P_n of the points *1*, *2*, $\cdots$, n and call a possible connection between any pair of points a diagonal. The closed path solution called the *minimum distance route* (mdr) is comprised of *sides*.

The *norma* is defined as a function that expresses the cost incurred, in added distance, by interrupting a diagonal through the insertion of a third point.

It is shown that any route is a constant multiple of a sum of normas and the difference between two routes represents a statement of order between normas.

For a route to be mdr, certain *first* order conditions must hold. These order relationships between normas are deduced in general and shown to be both necessary and sufficient in P_5.

It is shown that an ordering of normas with respect to all diagonals joined at a point partitions the set of all routes into two classes; one containing the mdr, and the other containing no candidate for the mdr.

Elimination of a diagonal as a possible side of the mdr reduces the number of possible routes from $(n-1)!/2$ to $(n-3)!/2$; subsequent diagonal elimination produces a somewhat lesser reduction, due to overlap.

Many diagonal elimination theorems are presented, and necessary conditions for a diagonal to be a side of the mdr are developed.

C. 5. Theory of Conflict

Location: PARLOR B

Chairman: PETER COLE, *Institute for Naval Studies, Cambridge, Massachusetts.*

C5a. The Distribution of the Time-Duration of Stochastic Duels, C. J. ANCKER, JR., and A. V. GAFARIAN, *System Development Corporation, Santa Monica, California.*

The Theory of Stochastic Duels is extended by considering the distribution of time-to-completion of the fundamental duel. The model has fixed kill probabilities and either random or fixed time between rounds fired. Time-limitation is included. Special cases and examples are worked out. Clearly, the time-duration of combat has both tactical and logistic implications for the decision-maker.

C5b. On Developing Models of Conflict, ROGER L. SISSON, *University of Pennsylvania, Philadelphia, Pennsylvania.*

Conflict is a very complex process. Experimentation in conflict can be based on a wide variety of models ranging from the elementary prisoner's dilemma to realistic games. Choice of the model is central to the research strategy. A taxonony of conflict models is presented based on: number of participants, extent and form of communication, complexity of the environment, and detail in representation of behavior (including goal structures). Conflict is defined as a situation in which more than one decision-maker is attempting to control a set of activities. This concept is made precise by a definition, due to Ackoff; the degree of conflict as seen by decision-maker, r; is

$$DC_r = \sum_i \sum_j P_i E_{ij} U_j - \sum_i \sum_j P_i \hat{E}_{ij} U_j$$

where P_i = probability r will choose course of action i,
E_{ij} = probability outcome j will result if i is chosen, with other decision makers attempting to control the activities,
$\hat{E}_{ij}$ = this probability, in the absence of other decision-makers, and
U_j = value of outcome j to r.

A decision-maker is said to have control over a subset of the activities, if E_{ij} approaches $\hat{E}_{ij}$. Applied to a model, procedures for setting P_i represent behavior; E_{ij} represents the environment and U_j the goal structure. Communication can influence any of these factors. On-going efforts to study conflict are related to this classification of models. Results from research based on use of two levels of models are described.

C5c. An Inductive Theory of Dynamic Combat, SETH BONDER, *Systems Research Group, Department of Industrial Engineering, The Ohio State University, 156 W. 19th Avenue, Columbus, Ohio. 43210.*

Since Lanchester's early efforts to mathematically describe the dynamics of combat, military analysts have organized and extended the theory. Analysts have also attempted to validate the existing theory—a posteriori—with data from historical and recent battles. Some extension and validation efforts are briefly discussed in the paper to point out that the existing theory is deficient in not including; (1) a means of inductively evaluating the attrition coefficients or kill rates of the weapons employed in the engagement, (2) the mobility characteristics of both forces, and (3) the fact that the kill rates are not constant when either or both combatants use moving weapons. The paper is directed to removing these deficiencies.

The rate at which a weapon can destroy targets—the kill rate—is considered dependent on; (1) the range between weapon and targets and (2) accuracy, firing time and lethality factors many of which are stochastic, i.e., the kill rate is a nonstationary random process. Using the theory of Markov chains, the kill rate probability distribution is derived. The effect of varying the weapon system's acquisition, accuracy, firing time, and lethality characteristics on the distribution is demonstrated.

The kill rate formulation is used as an input to a Lanchester-type model of dynamic combat. The model explicitly includes mobility characteristics of both forces and the variation in kill rates as the range between forces changes. A typical engagement is analyzed and the trade-off between mobility and firepower demonstrated. The use of both the kill rate and combat models for evaluation of proposed weapon systems is discussed.

C5d. Operational Problems in Static and Dynamic Calibration of a Newly Developed Scoring Device for Aerial Targets, ROGER W. WINSLOW. *Stanford Research Institute, P.O. Box 316, Fort Ord, California.*

The working principles of the acoustic miss distance indicator developed for the Army Aircraft Survivability Experiment (CDCEC 1963–1964) will be described. Curves showing the effect of range and angle of penetration on the energy level of super-sonic projectiles as recorded by the scoring system are given. Two systems will be discussed, one based on the time difference as a projectile passes a series of microphones, the second converting the bullet's super-sonic shock wave into an electronic pulse amplitude. The merits and shortcomings of each system are included. The paper will include a discussion of the operational problems of calibration and data collection with the newly developed equipment. Also included is techniques for system reliability and validity testing. A fully automated computer data reduction system is used to produce the miss distance output.

C5e. Field Experimentation in Operations Research, FRANK J. HARRIS, *Stanford Research Institute, Research Office, U. S. Army Combat Developments Command Experimentation Center, P.O. Box 316, Fort Ord, California.*

This paper describes the development and operation of a unique project based on field experimentation, but expanded over time into a more comprehensive operations research program. Critical to this development is the integration of sophisticated data collection devices and analytic (computer) tools. Emphasis will be placed on the sequential and integrative nature of experimentation components. With the advent of automatic position location systems and weapons effects devices, which will be described, the long hoped for two-sided field experiment with assessment and reduction of data in real time becomes within the state of the art. An experiment on Army aircraft survivability will be described by way of illustrating the foregoing points.

C5f. Low Altitude Penetration Parametric Study, P. T. CHAN, C. W. WEST, and F. M. WEINBERGER, *Vought Aeronautics Division, Ling-Temco-Vought, Inc., Dallas, Texas.*

Defense capability has been greatly improved by recent advances in anti-air weaponry. In order to increase survival of tactical aircraft penetrating enemy territory, it is necessary to degrade effectiveness of the defense by forcing it to operate under unfavorable conditions. Low altitude penetration affords increased survival by using terrain masking, which reduces both early warning detection and available firing time, and induces additional errors in the defense weapon systems. On the other hand, low altitude flight involves risk of collision with terrain. This hazard is increased if high penetration speed or flight over rough terrain is required. In order for survival to be assured or maximized, penetration speeds and altitudes must fall within a region bounded by several constraints. These constraints are imposed by the mission requirements, crew tolerance to aircraft maneuvers introduced by the terrain-following (T-F) system, crew tolerance to atmospheric turbulence, terrain roughness, and defense environment through which the penetration is to be made. It is the objective of subject study, performed under ONR

(Office of Naval Research) Project No. LTV-493-49, to examine these problem areas and to provide parametric reference data for determination of performance criteria for future system developments.

C5g. A Model for Allocating Defense Resources, Peter D. Fox and Iram J. Weinstein, *Stanford Research Institute, Menlo Park, California.*

The problem considered is that of allocating resources to an antiballistic missile defense system so as to minimize the maximum damage that an enemy can achieve in targeting U. S. cities, given constraints on both the defense budget and the offense attack force. The problem can be viewed as a two-move sequential game in which the offense has the last move.

The defense must determine which cities to defend, the level of the defense at each city, and the allocation of the budget for interceptors as well as for radars and other fixed equipment. A computational procedure involving the use of Lagrange multipliers has recently been described by George E. Pugh (*Opns. Res.* 12, 543–567 (1964)). His approach assumes that the individual targets or cities are independent except in so far as they compete for defense and offense resources. A variation on the Pugh formulation is presented that relaxes this assumption. In some cases, the new model is also better able than is the Pugh model to handle certain types of constraints that are political in nature. A cost-effectiveness framework for presenting results is described.

C. 6. Meeting of the Transportation Science Section

Location: Ballroom East

Chairman: Robert S. Foote, *Port of New York Authority, New York, New York 10011.*

C6a. Statistical Study of Factors Influencing Safety at Highway-Rail Grade Crossings, Leon Wester, *I.I.T. Research Institute, Chicago, Illinois,* and Gerald M. Magee, *Association of American Railroads.*

This paper presents some results of a study undertaken to determine factors influencing safety at highway-rail grade crossings. Data on crossings and accidents were analyzed to determine correlations between crossing characteristics and accident rates on highway crossings of twelve railroads operating in the State of Ohio. In addition, risk factors were obtained by statistical methods for these crossings.

Statistical techniques were used to show that accident rates are independent of angle of intersection of railroad tracks and highway, but correlate with other crossing characteristics. In particular, type of protection, visibility from highway, highway grade, volume of rail traffic, speed of rail traffic, volume of vehicular traffic, and number of tracks and spurs have a significant effect on accident rate at a crossing. Prediction equations were derived to compute risk factors for crossings protected by painted crossbucks, flashing lights or automatic gates. The relationships between expected risk factor and change in (1) highway traffic volume and rail traffic volume, (2) highway traffic volume and number of tracks and spurs, and

(3) highway traffic volume and speed of rail traffic, for given conditions of the remaining crossing characteristics, will be shown on slides.

C6b. Computer Simulation of Peak-Hour Passenger Movements on the PATH (Port Authority Trans-Hudson) System, James J. Browne, *The Port of New York Authority, New York, New York, 10011.*

In 1962, The Port of New York Authority, pursuant to legislative action in New York and New Jersey, assumed responsibility for operation and rehabilitation of the Hudson & Manhattan Railroad. For over seven years the private company which had operated the railroad was in bankruptcy reorganization proceedings.

Soon after acquiring the Hudson & Manhattan Railroad, which it operates as PATH (Port Authority Trans-Hudson), the Port Authority set up a study team to develop means of measuring existing traffic patterns and service levels and predicting the effects of changes in schedules and operations. Since there had been numerous suggestions from the traveling public and the operating staff, a method of evaluating the service improvements that each would achieve was needed. The result was an IBM 7070 program, developed by the study group, which simulates passenger movements over a period of time. Once a schedule consisting of a set of terminal departure times and associated train lengths is provided (along with stored train running times, passenger arrival and boarding patterns), the program calculates for each station the train departure times, number of passenger arrivals and the number boarding while checking critical points for operational feasibility. The program, in effect, follows each train from station to station keeping track of the time and the number of passengers on board—all based on internally stored facts and data.

Measures of service based on the simulation results were developed and used in evaluating many alternate schedules and operating techniques. The best of these have been implemented while changing conditions have developed a continuing use of the program. The simulation is quite flexible and is being used to investigate a variety of operating and planning possibilities. .

C6c. A Time - Dependent Queueing Model and Application to Airport Delays, K. G. Grossman and R. C. Wheeler, *Airborne Instrument Laboratory, Deer Park, Long Island, New York 11729.*

A time-dependent, single-server, first-come first-served queueing model is developed for arbitrary input and arbitrary service. Inputs to the model consist of a time-dependent demand and a service-time distribution which also may be time-dependent. Outputs consists of the delay vector as a function of time, and the first two moments. Properties of the model are discussed, numerous curves are presented, and application is given to an airport-congestion problem.

C6d. Fast Time Simulation of a High Performance Terminal Area Traffic Control System, R. W. Simpson, *Assistant Professor, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Results are available from a fast time simulation on the IBM 7094 of an advanced method of providing sequencing and spacing control for air traffic in the terminal area using the ILS bad weather approach. The particular method used involves flying a landing control pattern defined by a VOR-DME placed at the outer marker of the ILS, and, with a minimum runway interval of 90 seconds, demonstrates a capacity of 32 landings per hour with runway availability for 20 takeoffs. The total operations rate is roughly double present performance and approaches the theoretical capacity limit defined by the ILS funnel operation (Blumstein). The results provide an example of the value of fast time, detailed simulation of a complete terminal air traffic system, and demonstrate the capability to reproduce exactly previous traffic situations in order to investigate the effects of changing a single traffic parameter such as wind, traffic mix, descent rates, etc. It also provides an example of using the digital computer as a decision making control element, and gives some indication of its performance and the care and effort which must be taken to produce a working, safe, automatic controller.

C6e. Optimum Control of an Unsaturated Artery, J. Johnson, *IBM Data Processing Division, Yorktown Heights, New York.*

A progression system with minimum trip time is proposed for the Optimum Control of an Unsaturated Artery. Relations are developed to express trip time, progression flow, and constraint (on speeds, cycle lengths and bandwidths), as functions of the speeds on the artery in the two opposing directions. These relations are discontinuous, so a combinatorial procedure is developed for generating all possible through bands and the values of cycle length where discontinuities occur. The minimization problem is formulated as a non-linear program with non-linear constraints. Finally, suggestions are made for further refinements and extensions, for example, to grid systems.

FRIDAY NOON, MAY 7, 1965

(12:15–1:45)

Luncheon

Location: Ballroom East

Speaker: Kenneth E. Boulding, *Professor of Economics,*
University of Michigan.

Subject: **The Ethical Implications of Rational Decision**

FRIDAY AFTERNOON, MAY 7, 1965 SESSION D

(2:00–5:00)

D. 1. Practical Theories of Inventory Control

Location: Georgian Room

Chairman: Jerome D. Herniter, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

D1a. Aggregate Inventory Management, ROBERT G. BROWN, *Arthur D. Little, Inc., Cambridge, Massachusetts.*

An inventory *control* system is a formal procedure for posting disbursement, receipt, and adjustment transactions, and for issuing replenishment orders on the source of supply. The decisions when and how much to order are guided by numbers, such as an order point and an operating level. An inventory *management* system accepts information about the environment, such as costs, forecasts, lead times, and management policy, and occasionally revises the control numbers. The forecast is a time-dependent probability distribution that may be computed from past data, or modified or replaced by a subjective prior distribution.

The functional form of the equations used in the management system for revising the control numbers (e.g., order point and operating level) represents a particular *strategy* that governs the relative allocation of stock investment, customer service, and reordering workload among the items in the inventory. The strategy corresponds to a curved surface describing the expected investment as a function of workload and service. The surfaces for the aggregate effects over an entire inventory sometimes exhibit troughs or local minima that have important consequences in recommending the best strategy for a given inventory. *Policy* variables (such as service objectives and carrying charges) are parameters that define a particular operating point on the aggregate surface. Top management can select a rational policy that can be put into practice through a clear understanding of the implications of these aggregate effects of strategy and policy on total investment, total customer service, and total reordering workload.

D1b. Product Line Evolution in the Retail Store, GEORGE R. MURRAY, JR., *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Traditional formulations of the inventory problem model the inventory system of a production source or of a distribution point connecting the production source to the retail outlet. Such models are normally inappropriate for a retail store. A more realistic representation of the retail inventory problem treats demand as a function of the on hand inventory, recognizing that the display size and the competition from substitutable items are important factors in determining the sales of a particular item. Also the retail inventory is usually constrained to have a physical volume compatible with the store size. As a result of these differences in the models the retail inventory problem is qualitatively different from the better known wholesale inventory problem. The important decisions to be made are: which vendors to represent; what product line to carry; and how much space to allocate to each item. The decision of when to place a replenishment order to a vendor can be made with the aid of a variety of mechanisms, but the average retail store can justify economically only the very simplest of such methods. Consequently the reordering aspect of the retail inventory problem is of secondary interest. This paper examines the major decisions listed above in terms of the knowledge of the market available to the retailer from actual sales experience. An experimental program is considered whose purpose is to improve the understanding of the market and to continually evolve a more profitable selection of products and allocation of space.

D1c. Applied Inventory Models, T. M. Whitin, *Wesleyan University, Middletown, Connecticut.*

Applications of inventory theory during the last 15 years have been, for the most part, only the simplest types of inventory models, typically the economic lot size model. In several applications of this model, aspects have been ignored which are important from both theoretical and practical points of view. Examples will be given.

Only recently have studies been possible relating more complicated inventory formulations to simpler models. These studies have been made possible by the construction of more adequate models and the availability of high-speed electronic computers. Comments on cost comparisons of models of varying degrees of complexity will be made.

Finally a discussion of the possibilities of incorporating economic price theory aspects into applied inventory models will be given.

D1d. An Empirical Study of Exactly and Approximately Optimal Inventory Policies, Harvey M. Wagner, *Stanford University.*

The (s, S) inventory model (infinite horizon with stationary parameters) is explored with a view toward determining the dependency of the optimal policy on the model's parameters and toward evaluating the effectiveness of several numerical approximation methods for obtaining nearly optimal policies. The mode of attack is empirical: We compare the results for 828 cases, which encompass several values for each of the economic parameters, three delivery lags, and three distinct demand probability distributions with varying parameter values. We demonstrate for these cases that close to optimal results can be obtained by applying the Fibonacci search procedure, by using a particular asymptotic approximation, as well as by substituting a certain policy not of the (s, S) form.

D. 2. Experimentation In Operations Research, (A Panel)

Location: Stanbro Hall

Chairman: Hugh J. Miser, *The MITRE Corporation, Bedford, Massachusetts.*

D2a. Observation and Experimentation in Operations Research.

Panelists: Edward H. Bowman, *Massachusetts Institute of Technology,*
Robert S Foote, *The Port of New York Authority,* and
George R. Lindsey, *Defence Research Board of Canada.*

This session takes its point of departure from the belief that operations research is an experimental science, and, therefore, that observation and experimentation play a fundamental role in its development. However, there is much current concern among many OR workers that these aspects of our science are not receiving enough attention to assure it a balanced growth. As a step toward drawing attention to the need for redressing the balance, this session will bring together in a panel discussion a group of operations research workers, each of whom has had extensive experience in observation and experimentation in his chosen field of OR. Such matters as these are candidates for discussion at this session: methods of obtaining and recording data from actual operations, recording devices used by OR workers, planning experiments and trials, planning the analysis of OR data, the feasibility of observation of and experiments with large-scale operating systems, the training of OR workers for roles in observation and experimentation, the role of "clinical work" in the education of operations research workers, the problems of military and industrial classification as barriers to publishing experimental and observational findings in OR, the role of observational and experimental results in formulating OR models and theories, and so on. In order to single out the issues of greatest mutual concern and concentrate on them, the session will have three parts: In the first part, after an opening statement by the chairman, each panelist will make a brief statement; in the second part, the panelists will comment on these statements; and, in the third part, the audience will be asked to join the discussion.

D. 3. Contributed Papers on Transportation and Distribution

Location: PARLOR A

Chairman: PETER B. WILSON, *Canadian National Railways, Montreal, Quebec, Canada.*

D3a. Most Profitable Routing Before Maintenance, CHRISTOPH WITZGALL and A. J. GOLDMAN, *National Bureau of Standards, Washington, D. C., 20234.*

An algorithm based on dynamic programming ideas is given for the following problem. A vehicle yields profit $p(i, j)$ whenever it goes from City i to City j, and requires $t(i, j)$ hours to do so. Before travelling more than T hours, it must receive maintenance of a kind available at only *some* of the cities. How should the vehicle be routed, from a given starting point, so as to maximize total profit before maintenance? The method extends to the case of several types of maintenance, available respectively at several different subsets of the cities.

D3b. An Airport Capacity Handbook: Results of a Federal Aviation Research Program in Mathematical Models and Techniques for Determining Airport Capacity, OSCAR SHAPIRO, *Federal Aviation Agency, Research Division, Atlantic City, New Jersey.*

A Research Program instituted by the Federal Aviation Agency has resulted in the development of a handbook with general applicability for determining airport arrival-departure capacity and delays. It is intended for use by airport planners and designers who are not operations research analysts. This Airport Capacity Handbook has been published by the Agency as well as the Government Printing Office so as to have the widest possible availability. It is the purpose of this paper to summarize the background material relevant to the handbook and describe the mathematical models and techniques utilized. The criteria for capacity are expressed as a function of acceptable delay and aircraft population. The input variables employed are runway figuration, runway use, aircraft population and operating rules (VFR or IFR). The airport surveys that were analyzed to provide the input values and to test the results are also described as well as the solutions obtained, using an IBM 7090, of the mathematical equations derived from the application of queueing theory. Finally, the results, in the form of aircraft delays as a function of the pertinent variables, are illustrated.

D3c. A Study of Car-Pool Systems in Railroad Transportation, B. AVI-ITZHAK, BENJAMIN A. BENN, and BRUCE A. POWELL, *Case Institute of Technology, Cleveland 6, Ohio.*

A rather common type of service supplied by railroad companies is the so-called car-pool service where a pool of specially equipped cars is assigned for the sole use of one shipper or a small group of shippers. In this paper a probabilistic approach is used to develop models describing the behavior of a large variety of such systems. Cost equations relating pool size, round-trip times and quality of service are constructed and studied. A method of estimating required sizes of new pools is suggested. The results are used to study some actual car-pool systems and a case study is presented.

D3d. An Operational Solution of a Large Scale Delivery Problem, RALPH BOEKEMEIER, *Continental Copper & Steel Industries, Inc., 100 East 42nd Street, New York, New York. 10017.*

Frequently the analyst is faced with a problem so complex that rigorous solutions are feasible only with a serious departure from realism, and by the omission of fertile solution alternatives which become available under actual operating conditions. A product delivery problem involving several thousand destinations and uncertainty of outcome is an example of this situation. An operational solution to this problem is described in which analytical results lead to simple route labeling procedures and data displays. These displays convert the computational impasse into problems of visual pattern recognition which can be quickly resolved. Criteria are established for monitoring actual operating results for solution validity using methods of statistical control. These criteria indicate when a particular solution should be re-examined, and where problem re-entry should occur.

D3e. Aerospace Systems Approach Applied to Regional Transportation Planning, JOHN H. TINLEY, and SIDNEY MOGLEWER, *Douglas Aircraft Company, Inc., 3855 Lakewood Blvd., Long Beach, California.*

Transportation planning in the past has lacked the means of effectively evaluating the total interrelated integrated transportation system. This paper will illustrate the appropriateness of adopting procedures common to the military aerospace field for transportation planning. These procedures are aimed at eliminating the above deficiency in present transportation planning.

A significant feature of the military requirements and weapons procurement process has been the establishment of a formal evaluation methodology that determines alternatives and consequences for the decision-maker. This evaluation methodology could be utilized in transportation planning. Further, this evaluation methodology embedded in a total systems approach can provide the necessary perspective for meaningful evaluation of today's complex transportation problems.

The techniques of operations research then could provide the structure for such an evaluation.

A description of the resulting approach as applied to transportation planning is presented with an identification of significant areas for further development. It is shown that an aerospace systems approach combined with operations research techniques offers a promising procedure to reduce the transportation problem to manageable dimensions.

D3f. Optimal Route Assignment for Metropolitan Road Traffic, ALAN HERSHDORFER, *Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A trend in metropolitan transportation planning has been the utilization of computer programs to assign transfer volumes to roads, based on calculation of sequences of minimum time paths. Such programs optimize neither system performance nor improvement effectiveness; they remain tools for simulating the effects of ad hoc network changes. Little attention has been given to formulating the assignment problem as a multicommodity flow linear program. The solution determines multicommodity feasibility and places a lower bound on time costs calculated by "traditional" assignment programs. We extend the model to determine the optimum allocation of existing lane capacity, in particular the arrangement of one-way streets. A mixed-integer program is solved by the branch-and-bound algorithm on the IBM 7094; time-sharing permits immediate evaluation of any configuration. Branch-and-bound is applied to the synthesis problem (similar to the fixed-charge warehousing problem) of determining the minimum addition which improves the system cost by a specified amount. Imbedding the algorithm within a dynamic program determines optimal scheduling of improvements. The decomposition algorithm is applied and specialized: submatrices generate programs solvable by the out-of-kilter algorithm; the repetitive and sparse matrix permits greater computer storage economies.

D3g. A Study of a Motor Bus Undertaking, J. G. CROOKES, *British European Airways, London Airport, England,* K. B. HALEY, *The University, Edgbaston, Birmingham 15, England,* and P. J. PENGILLY, *Proctor & Gamble Limited, Newcastle Upon Tyne 3, England.*

Past performance was used to predict the future of the undertaking. A prediction model for income was constructed and tested. The model was used to predict the future of the enterprise and types of managerial policies were examined. A particular policy was shown to be preferable. Before making the organisational changes required, a productivity measure was applied to the system to ensure that the change in responsibilities envisaged would cause no harm. The results of the project were sold to the management committee and have been fully implemented.

D3h. Necessary and Sufficient Conditions for a Solution to the Multifacility Production-Transportation Problem with Non-linear Production Costs, J. FRANK SHARP and H. R. PRASAD, *Industrial Engineering Department, Rutgers—The State University, New Brunswick, New Jersey.*

A production-transportation model is formulated for a firm with several plants supplying several markets. The production costs at each plant are non-linear while the transportation costs between each plant-market pair are assumed to be linear. The objective is to minimize the sum of production and costs while meeting given market demands. Necessary and sufficient conditions for an optimal solution are obtained and interpreted.

D3i. A Computer Program for Automatic Planning of Logistic Airlifts, HANS J. BERLINER, *Washington Systems Center, I.B.M., Bethesda, Maryland.*

In connection with studies of future Air Force Command & Control requirements a computer program has been developed which accomplishes the planning of logistic airlifts with no human intervention. Before the start of the program, the planner selects certain mandatory and optional inputs from among arrays of alternatives. These then provide goals and constraints to the computer program. Taking cognizance of these initial conditions, the program then successively calculates the logistic requirements, locates sources for these requirements, configures transport aircraft loads of supplies, generates aircraft routes, and schedules the whole operation. These program sections accomplish such tasks as selecting the most efficient aircraft from a list of those available, locating enroute refueling bases for aircraft, and detecting and avoiding overflight of previously specified territories. The logic of the whole planning sequence, including decision points for advancing to the next state or looping back to a previous state, is included in the program. The initial conditions given by the planner, together with a data base which furnishes information on air bases, material stockpiles, aircraft characteristics, etc., determine what choices the program makes at decision points and thus the final form of the output. The whole program will be running during March 1965 and results of computer runs will be presented.

D. 4. Contributed Papers on Quantitative Bases for Investment Decisions

Location: BALLROOM WEST

Chairman: GERSHON COOPER, *Dunlap & Associates, Darien, Connecticut.*

D4a. Risk Measurement in Capital Investment Decision-Making, NORMAN N. BARISH and SEYMOUR KALAN, *Department of Industrial Engineering and Operations Research, New York University, New York, New York, 10453.*

Attempts have been made in recent years to introduce concepts involving risk and uncertainty into capital investment decision-making models. The measure of risk for individual projects is usually taken to be the variance of the project payoff, under the assumption that the payoff for each project is a random variable whose probability distribution can be obtained in some manner, frequently from an estimate of the probability distributions of the annual cash flows of the projects. These cash flow distributions need not be, and in many cases are not, symmetric or even unimodel and the variance will then sometimes be a poor decision-making measure for the risks involved in the undertaking. Examples of such situations are given. Alternative measures of risk for some of these situations are presented and discussed. The problem of estimating the general shape of the distribution of payoffs is also examined.

D4b. Expected Value of Options, Warrants, and Convertible Securities, ALAN W. HARBAUGH, *Dunlap & Associates, Inc., 1454 Cloverfield Boulevard, Santa Monica, California, 90404.*

In this paper a mathematical relation is obtained for the expected value of an option to purchase or sell common stock, based on the lognormal distribution of stock price movements. Results show good agreement with empirical data on put and call options, including results of the SEC option study. The analysis is extended to warrants, convertible preferred stocks, and convertible bonds. The relations are readily adapted to machine computation and printout for use by securities analysts.

D4c. Stochastic Decision Trees for the Analysis of Investment Decisions, RICHARD F. HESPOS, *McKinsey & Company, Inc., 270 Park Ave., New York, New York,* and PAUL A. STRASSMANN, *National Dairy Products Corporation, 260 Madison Avenue, New York, New York.*

This paper describes an improved method for investment decision making. The method, which is descriptively called the stochastic decision tree method, is particularly applicable to investments that are characterized by high uncertainty, and which require a sequence of related decisions to be made over a period of time. The stochastic decision tree method builds upon concepts used in the risk analysis method and the decision tree method of analyzing investments. It permits the use of subjective probability estimates or empirical frequency distributions for some or all factors affecting the decision. This application makes it practicable to evaluate all or nearly all feasible combinations of decisions in the decision tree, taking account of both expected value of return and aversion to risk, thus arriving at an optimal or near optimal set of decisions. Sensitivity analysis of the model can highlight factors which are critical because of high leverage on the measure of performance, or high uncertainty, or both. The method can be applied relatively easily to a wide variety of investment situations, and is ideally suited for computer simulation.

D4d. Developing Objective Criteria for the Design of More Nearly Optimal Investment Decisions in Pension Fund and College Endowment Investment Management, HANS H. JENNY, *Office of Institutional Research, The College of Wooster, Wooster, Ohio.*

The paper summarizes two chapters of a forthcoming study on optimum portfolio selection. It develops several objective criteria which will serve as minimum quantitative targets in the guiding of investment decisions. In each case appropriate functions to be maximized will be set forth. The paper furthermore makes use of certain simulation techniques—some of which are in use today in pension fund and college endowment management—to show differences in performance. It will be possible to show, for instance, that the application of specific optimization techniques yields consistently superior performances than the less formal traditional methods. Several case histories will be summarized to show just how performance can be improved. It is expected that a more widespread application of the methodology and simulation techniques described in the paper may contribute significantly to enhanced performance in pension fund and college and university endowment investment management.

D4e. The Developing of Investment Strategies Through Application of Econometric Processes, J. JEFFERSON PARKS, *Parks-Ross Company, 13794 Beach Blvd., Westminster, California.*

The ability to formulate schedule, financial and technical performance parameters for investment potential, and further describe causal relationship between these factors, allows the entrepreneur to evaluate, with precision, risk/return-on-investment ratios. Assignment of quantitative value ranges to the above parameters establishes a scientific environment for making trade-off decisions and pre-testing their impact upon investment objectives. Essentially, this process affords the decision maker a series of alternative selections to choose from when structuring his investment strategies.

D4f. Investment Planning Simulation, Z. SZATROWSKI, *Service Bureau Corporation, 635 Madison Avenue, New York, New York, 10022.*

This simulation considers investment activity as the allocation and utilization of resources among various alternatives, where the objective is to realize maximum future net value. The analysis, and IBM 7094 computer program, is designed to designed to generate the results of a given investment plan or method in a given (past or hypothetical) investment environment. In addition, the analysis yields various kinds of information about various possible results in a given investment environment. For example, it is possible to determine the best results (potential), the 2nd best, median, etc. results. Also it is possible to generate (through successive Monte Carlo simulations) the probability distribution of results where investment decisions are done by chance. The Monte Carlo simulation results enable the planner to determine the probability of realizing any specified investment result and the resulting probabilities provide a basis for evaluating investment plans, changes in plans, etc. The design of the simulation is similar to that of a laboratory experiment where an attempt is made to reproduce the significant aspects of the real world situation but not all of the details. The simulation has general application in investment planning. Particular applications would be portfolio analysis, allocation of research expenditures, planning capital improvements, etc.

D4g. Dominant Decision Rule for Multistage Allocation Processes Under Risk, MARK ALFANDARY-ALEXANDER, *Operations Analysis Division, Atomic Energy Commission.*

A decision-maker is in an environment where resources have to be commited subject to random outcomes. The amounts allocated can vary continuously or discretely within given bounds. These bounds remain constant for *all* the stages in the process.

A strategy is given which dominates known decision rules for this class of problems. This strategy uses a feedback concept to continually readjust allocations at each stage.

If the constraint of bound invariance is relaxed and the allocation upper bound is allowed to vary randomly, then a more complicated strategy seems necessary.

A motivation for the above study has been the r-&-d budgeting process.

D. 5. Contributed Papers on Selected Topics in Operations Research

Location: PARLOR B

Chairman: RICHARD MEYERS, *Harbridge House, Boston, Massachusetts.*

D5a. Forecasting by Intrinsic Versus Extrinsic Models, Y. KURATANI and Y. S. CHIDAMBARAM, *Case Institute of Technology, Cleveland 6, Ohio.*

When a forecaster decides to use regression method to forecast future values of a variable of his interest, he is often confronted with the problem of choice between what may be termed an "intrinsic" forecasting model and an "extrinsic" forecasting model. The former is the model which uses only information of the past values of the variable to be predicted whereas the latter is the one which uses a function of external variables as the predictor. Essentially, smoothing techniques which are now quite popular among management scientists belong to the former category and enconometric forecasting method which are being widely used by economists belong to the latter category. In this study the authors report on their efforts in developing general principles which provide a useful guide to a sensible choice between the two competing approaches.

Simple illustrative models will be presented.

D5b. The Lockheed Multiprocessor Simulation System, JOHN N. MAGUIRE, *Lockheed Missiles and Space Company, Sunnyvale, California.*

The Lockheed Multiprocessor Simulation System (LOMUSS) provides a capability to solve complex systems analysis problems through simulation. LOMUSS was developed as a result of the need for a predictive, experimental model of a generalized data processing system and is a 7,500 SIMSCRIPT instruction program which operates on an IBM 7090 or 7094 computer. The range of application areas to which LOMUSS has been applied extends from Data Processing to Manufacturing systems. The purpose of this paper is to describe the problems in the simulation approach and how LOMUSS assists in their solution. The structure of LOMUSS is presented along with the process of applying LOMUSS where the user constructs a model and conducts experiments solely through data cards. The information on the data cards represents, (1) the resources of a model in terms of men and machines to the level of detail required and, (2) the demand in terms of jobs requiring various amounts of work and combinations of machines in many different sequences. Detailed information is retained during the simulation for the compilation of multilevel summarizations, snapshots, job performance, and periodic reports for user analysis. The significant capabilities of LOMUSS in comparison to job-shop simulators are presented along with examples of LOMUSS use in areas such as: Computation Center Management, Hospital Systems Design, Manufacturing Planning and Control, and Traffic Flow Analysis.

D5c. Military Personnel System Simulation, George O. Wright, *1000 6th Street, S.W., Apt. 206, Washington 24, D. C.*

This paper will describe a personnel system simulator designed and operated for the officials of the Deputy Chief of Staff/Personnel, Department of the Air Force. Details will be given of the design concepts, experience in operating the simulator, and some examples of the typical problems handled.

The discussion of the design concepts will include the core-façade principle in which the simulator program contains a semi-invariant core of general routines and a façade of specialized sub-routines. Under this design concept the simulator has a flexibility for handling a variety of problems by changing the sub-routines rather than the entire program. Included also will be the concept of human-in-the-loop. The simulator is designed so that input variables have to be furnished by managers. In addition, halts are inserted so that the manager can examine the interim solutions and choose the conditions for the next phases of interation. This interation between man and machine is continued until a satisfactory solution to the management problem is obtained.

The paper will discuss also some examples of problems run on the simulator dealing with proposed promotion policy changes. Some attention will be given also to a current development to incorporate on-line remote computing into the simulator. Under this plan the manager interacts on-line with the simulation program via a display console and a tele-typewriter.

D5d. Operations Research—or Systems Engineering—Analysis of the Relative Satellite Reconnaissance Effectiveness for Pre-launch Programming versus In-flight Operations Programming, Peter J. Johnson, *Dept 59-16, Lockheed Missiles and Space Company, Sunnyvale, California.*

This study was undertaken to develop an engineering basis for the evaluation of the relative satellite reconnaissance system effectiveness of a system employing (only) pre-launch operation programming versus that of an otherwise equivalent system with capacity for in-flight operation programming. From the concept of the problem, differences in system effectiveness would arise in a situation where satellite reconnaissance of any or all of a specified target array is desired. Analysis of the geographic location of the targets, their dimensions and weighted order of importance, considered with the satellite system orbit capability variables, define an optimum "nominal" operational orbit (period, inclination, etc.). The first system alternative is constrained by the requirement fore *pre-launch* programming of the time-sequence of in-orbit operations to optimize system effectiveness for the prescribed orbit and probability distribution functions of actual operational characteristics. The second system would employ the additional capability of receiving a full program for operation *after* having been injected into orbit, the program optimized for accurately known orbit characteristics, subject to periodic revision by proper command communication from ground stations. The results of this study indicate that the coverage effectiveness of the system with in-flight-programming capability—for a specified target array—would be significantly greater than that for the pre-launch-programmed operation. The difference is dependent heavily upon the expected variance of the satellite system operational period error.

D5e. Entropy Maximization and Statistical Rescaling of Spacecraft Simulation Models, EMIL M. MURAD, *5316 Ocean Blvd., Long Beach, California, 90803,* and DENNIS M. GALVIN, *1134 Darby Street, Orange, California.*

Basically two methods are used to solve probabilistic problems: (1) analytic (closed form solutions) and (2) sampling (simulation) techniques. Quite often a complex mathematical model, for example of a manned spacecraft, is structured such that a pure analytic approach cannot be pursued due to the inability to write and solve the closed form equations while a pure sampling technique requires an uneconomical amount of computer time in which to achieve a solution at a reasonable level of confidence. This paper treats such a problem by combining analytic and simulation techniques so as to tailor the computational procedure with the most efficient method of solution; namely, those aspects of the problem which are amenable to analytic methods are solved in closed form and those aspects which lend themselves to sampling techniques are solved using simulation.

The efficiency of machine computation is increased by statistically rescaling the simulation process in accordance with the closed form results and maximizing the "bit rate" of the processed data through the "computational channel."

The theoretical basis for this methodology is given by the concept of entropy in Information Theory and is analogous to accelerated (hyperenvironmental) testing so as to accumulate statistically significant numbers of incidents during comparatively short test times.

D5f. A Mission Cost Model for Ferret Satellites, H. C. SEBRING, *Missile and Space Division, General Electric Company, Philadelphia 1, Pennsylvania.*

An analytical model to evaluate ferret satellite systems is explicated. It may also be used to yield inputs for specific system definition. In addition to the general stochastic nature of radar signal detection, analyses are applied to the cases of unknown emitter bandwidths and to the detection of known frequencies. The conditions of emitter operation and overflight are included. The signal detection probability is an input to a cost effectiveness methodology which also considers major parameters such as orbital altitude, payload weight, reliabilities, launching requirements and costs, weights and costs of satellites and ancillary equipment, and total mission cost to achieve objectives with predetermined confidence. Logic is drawn from the model to support the conclusion that, ignoring safety factors, the niminum orbital altitude related to the desired lifetime is preferred. Numerical examples are presented; however the purpose of the paper is to document the analytical method. There is no application to specific systems that might be postulated.

D5g. On the Use of CEP in the Contractual Specifications of Weapons Systems: A Suggested Alternative, MELVIN BROWN, *Hughes Aircraft Company, Culver City, California.*

A rule of thumb method is derived for reducing a sample of statistically independent data, obtained from an unbiased, circular normal distribution, so as to yield an unbiased, minimum variance estimate of the standard deviation of the parent distribution. It is suggested, as a corollary and application of this study, that contractual specifications for missile systems which refer to CEP be modified in future contracts in such a manner that these CEP specifications be replaced by corresponding specifications with respect to the 80th percentile radius. The effect of such a replacement is to increase the precision with which miss distances are estimated when the missile systems are flight tested.

D5h. Systems Engineering and Operations Research—An Inquiry into Methodology, Robert L. Porter, *Clark, Cooper, Field & Wohl, Inc., 122 High Ridge Road, Stamford, Connecticut.*

Systems engineering and operations research both have the same basic purpose, i.e., to aid in the solution of practical decision problems that occur in developing and operating complex man-machine systems. A rational approach to resolving decision problems calls for the development of new knowledge to reduce the uncertainty in the decision situation. Since new knowledge is developed by employing the scientific method, it follows that systems engineering and operations research have the same underlying methodology, namely, the application of the scientific method to the solution of practical problems in government and industry. This conclusion is accepted only after resolving differences between systems engineering and operations research regarding personnel, the types of problem attacked, the concern with equipment design, etc. Some implications of the conclusion are that these activities should not be limited to quantifiable problems involving maximization of some criterion function, and that operations research should not exclude equipment design. In applying the scientific method to the solution of practical decision problems, one finds that no detailed techniques can be spelled out. Rather the basic methodology is described in terms of problem definition, choosing objectives, systems synthesis and analysis, and selecting alternatives.

D5i. An Application of Hand-played Gaming Techniques to Sub-system Effectiveness Evaluation, Frank Ichniowski and Edward Maslansky, *Social Security Administration, Department of Health, Education, and Welfare, Washington, D. C.*

One of the problems of analyzing a sub-system (ex situ) is the dificulty in assessing the consequences of changes in the subsystem as they affect the total system. A method is here discussed in terms of which the load on the sub-system is partially controllable by one player, and the ability of the sub-system to handle the load is partially controllable by the other player. The system is artificially reduced to a two-sided game. The control is affected both by built-in constraints and by various random factors affecting the system. Player "A" (controlling the input) attempts to saturate player "B" (controlling the service); the effect is to require player "B" to tailor the service capability to the strategies of player "A", both in the light of the stochastic elements defining the character of the system and in the light of the perversity inherent in the best strategies of player "A". Game solutions are developed, and may or may not be unique; game complexity is a variable, and may be altered as a preset. A specific application of this method is described and evaluated.

D5j. Productivity and Quality Cost Approach to Analyzing Operator Effectiveness, J. R. WOLTZ, S. SOOVAJIAN, and W. EICHHORN, *I.B.M., Kingston, New York.*

This paper describes the results of a research activity in the field of work effectiveness. The goal of this activity was to develop an operator measurement system based on the quality of the product produced by the manufacturing operator as well as the time factor involved in producing the product. These two factors are tied together through a common denominator—cost.

D. 6. Operations Research in the Insurance Industry, (A Panel).

Location: BALLROOM EAST

Chairman: GORDON SHELLARD, *New York Life Insurance Company, New York, New York.*

D6a. Operations Research in Insurance.

The purpose of this session is to examine the status of operations research in the insurance industry, to review development of the present status, and to explore and evaluate potential future development. The nature, organization, and special technical aspects of an insurance business will be explained as the domain within which studies must be made. Some examples of the application of recognized operations research methods and techniques within the industry will be described. From these the panel will try to outline problem areas and approaches which appear to offer the greatest opportunity for further application of operations research in this field. Audience participation in discussion is invited and expected.

Panelists

DAVID H. HARRIS, *Equitable Life Assurance Society of the U. S.*
LEROY J. SIMON, *Actuary Insurance Co. of North America*
JOHN M. BOERMEESTER, *John Hancock Mutual Life Insurance Company*
NATHAN F. JONES, *Prudential Insurance Company*
JAMES T. BYRNE, *Metropolitan Life Insurance Company.*
BERNARD SHORR, *Travelers Insurance Company*
TIBOR FABIAN, *Mathematica*

Society Affairs

THE ORSA COUNCIL MEETING

The Twenty-Sixth Meeting of the Council of the Operations Research Society of America convened at 8:45 p.m. on 6 October 1964 in the President Washington Room of the Hotel Leamington Minneapolis, Minnesota, with George E. Kimball, President, presiding and continued at 2:10 p.m. on 7 October in the Milwaukee Room. The following items are reported from the Minutes of that Meeting.

FUTURE MEETINGS. The Spring 1965 Meeting will be held in Boston, Massachusetts, on May 6–7 with David M. Boodman as Chairman.

The Fall 1965 Meeting will be held in Houston, Texas on November 4–5, 1965, chaired by James A. Birdwell.

The Spring 1966 Meeting will be held in Los Angeles, California on May 18–20, 1966, chaired by John E. Walsh.

ORSA MEMBERSHIP. As of August 31, 1965 the ORSA membership totaled 4330. Of this number, 1537 were Members, 2391 were Associate Members, and 402 were Student Associate Members.

ORSA BROCHURE. It was decided that the brochure be updated and reprinted.

SECTIONS. It was decided that all Sections (both technical and geographic) would be required to submit an annual report at the Annual Meeting of the Council. The following prospective sections of ORSA are now under consideration:

Geographic:	Detroit	Moline, Illinois
	Ft. Lee, Virginia	Houston, Texas
	Denver	Dallas-Fort Worth, Texas
Technical:	Cost Effectiveness	

It was agreed that applications for status as Sections of ORSA must contain request for recognition, statement of aims, list of members and officers, and proposed constitution.

It was agreed that the Council approve the organization of the Cost Effectiveness Section, subject to the receipt by the Secretary of the formal application accompanied by a list of members and a reasonable constitution.

LANCHESTER PRIZE. The Lanchester prize was awarded to P. C. Gilmore and R. E. Gomory, A LINEAR PROGRAMMING APPROACH TO THE CUTTING STOCK PROBLEM—PART II, *OPERATIONS RESEARCH*, November–December 1963, pp 863–888, and Honorable Mention was given to papers by D. L. Iglehart and P. Wolfe.

NOMINATIONS. The following slate has been announced by the Nominating Committee (biographies and ballots are being mailed to the Membership separately):

President-elect	George Shortley
Vice President	John F. Magee John E. Walsh

Secretary	Joseph H. Engel
Treasurer	George J. Feeney
	Thomas E. Oberbeck
Council Members (2)	Newton A. Ablahat
	Ralph E. Gomory
	William S. Jewell
	Herbert K. Weiss

AAAS. The Council was provided with a written report of joint TIMS-ORSA Sessions on Managing the Innovative Process scheduled in conjunction with the AAAS Annual Meeting in Montreal, 30 December 1964. Papers from the session may be published in SCIENCE. It was agreed that ORSA would attempt to sponsor a joint session with TIMS at the AAAS Annual Meeting in December 1965, with Ellis Johnson again representing ORSA, and Burton Dean again representing TIMS.

NATIONAL SCIENCE FOUNDATION. Dr. John R. Lehman of the NSF was an "observer" at the TIMS-ORSA Meeting.

PRESIDENT'S ADVISORY STAFF ON SCIENTIFIC INFORMATION MANAGEMENT. It was the sense of the Council that the Society supports with enthusiasm Joint Resolution 202, to provide for the establishment of an agency in the Executive Office of the President to be known as the President's Advisory Staff on Scientific Information Management. (Note: The President will write the Committee offering assistance of ORSA in connection with hearings, etc.)

Mr. Locke described the development of the idea and the current state of plans for the establishment of a Cost Effectiveness Section and submitted a proposed constitution and a statement of goals of the prospective Section.

NEW MEMBERS. The Membership Committee reported its nominees for full Membership in the Society. A list of new Members elected is shown below:

Elected Members at 26th National Meeting

Arquette, Lester K.
Banack, Jerome J.
Bell, Lloyd Franklin
Biser, Erwin
Blake, Archie
Borkman, Karl John
Bowden, George Edwin
Breswick, William N.
Brown, Edward A.
Burns, Loren Virgil
Caldwell, Thomas Edward
Cameron, Donald A.
Cavadias George S.
Claitor, L. Carroll
Clelland, Richard C.
Cohan, Lawrence S.
Crawford, Lyndon
Cryer, C. Richard
Culberson, Oran L.
Davis, Edward W.
Day, Ralph Lewis
Dietz, Stephen Karl
Dix, David D.
Eberhard, Robert A.
Eckstein, Michael Eusey
Edelshon, Charles Robert
Eklof, Theodore Herman
Erikson, Warren John
Faucett, William Munroe
Flanagan, Robert J.
Fox, Joseph M.
Freund, David
Fuller, Alan C.
Gard, Orin P.

Gershon, Gordon Milton
Gleiberman, Leon
Gray, Paul
Hall, Donald Lewis
Hamberg, William A.
Hayward, Philip
Hemann, Raymond G.
Hunt, Arch William
Isaacs, Herbert H.
Isert, Irwin L.
Katz, Irving
Kelleher, Grace Jayne
Kiviat, Philip
Klimpel, Richard Robert
Krause, Lloyd I.
Kwerel, Seymour Matthew
Martin, Francis F.
Mercer, Alan
Metzger, Robert William
Milliman, Pierce D.
Mills, Harlan Duncan
Nanus, Burt
Partridge, William R.
PoKempner, Stanley J.
Pournelle, J. E.
Power, Clifton S., Jr.
Powers, Bruce F.
Roberts, Donald Merle
Rhee, Shi Young
Roherty, William F.
Rothaus, Albert Henry
Salz, Norman P.
Sanjour, William
Sawicki, Alfred Thomas
Schechter, Edwin
Schemmer, Benjamin Franklin
Sherrard, Emil S.
Shudde, Rex H.
Siegel, William
Slattery, Theodore B.
Sobelman, Sidney
Stinson, P. J.
Strum, Louie Willard, Jr.
Struve, Donald L.
Sullivan, Richard Joseph
Taylor, James Charles
Thompson, Robert John
Wahba, Grace Goldsmith
Wheeler, Richard Carrington
Woodall, Hunter M., Jr.
Young, Lawrence Franklin
Yovits, Marshall C.
Yudowitch, Kenneth L.

TREASURER'S REPORT

Santa Monica, California
March 2, 1965

Following is a statement of Cash Receipts and Disbursements of ORSA for the calendar year 1964. The report of the auditors accompanies this statement. A breakdown into two columns is used, with International Abstracts in Operations Research receiving special consideration. The method of statement is on an explicit cash basis with major obligations listed by note.

John E. Walsh
Treasurer

AUDITORS REPORT

Baltimore, Maryland
January 29, 1965

The Operations Research Society of America,
Baltimore, Maryland

We have examined the statement of cash receipts and disbursements of The Operations Research Society of American for the year ended December 31, 1964.

Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statement presents fairly the cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1964.

LYBRAND, ROSS BROS. & MONTGOMERY

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

For the year ended December 31, 1964

	Regular	*International Abstracts in OR*
Receipts:		
Members' dues	$29 471	$7 424
Subscriptions	25 384	17 422
Advertising, less commissions	14 386	
Sales of back issues	4 342	988
Royalties	3 501	
Interest	2 646	
Meetings, net	1 816	
Miscellaneous	116	
	81 662	25 834
Disbursements, as annexed	72 214	28 993
Excess of receipts over disbursements	9 448	(3 159)
Cash at beginning of year	72 022	19 363
Cash at end of year	$81 470	$16 204
Represented by:		
Petty cash funds	$575	$275
Demand deposits	5 895	15 929
Deposits with federal savings and loan associations	75 000	
	$81 470	$16 204
Portions of the cash balance are reserved as follows:		
Unearned subscriptions:		
Volume 13 (OR) to be issued in 1965	$15 000	
Volume 4 (#3 to 5) and Volume 5 (IAOR) to be issued in 1965		$9 400
Guarantee to publisher of the Society's series "Publications in Operations Research"	6 000	
Unpaid reimbursement vouchers and bills		500
	$21 000	$9 900

DISBURSEMENTS

For the year ended December 31, 1964

	Regular	*International Abstracts in OR*
Journal printing costs	$30 207	$19 921
Editorial and other expenses	9 169	1 207
Salaries and fees		3 283
Managerial services	17 787	1 500
Bulletin printing	3 133	
Publications in OR	196	
Printing and binding directory	4 063	
Travel expense		338
Council and officers' expenses (Note)	732	
General Society expenses	2 504	
Lanchester Prize	1 000	
IFORS Dues	851	
Supplies, materials, etc.		2 003
Auditing	300	
Committee expenses (Note)	2 008	
NSF Refund		781
Mail list	237	
Miscellaneous	27	(40)
Total disbursements	$72 214	$28 993

Note: Details of council and officers' expenses and committee expenses are:

Council and officers' expenses:

President	$334
Vice President	32
Secretary	366
	$732

Committee expenses:

Membership	$150
Prize	35
Sections	305
Nominating	138
Program	1 380
	$2 008

COST-EFFECTIVENESS SECTION OF ORSA

On October 7, 1964, the Council of the Operations Research Society approved the organization of a nationwide Cost-Effectiveness Section within ORSA, subject to receipt, by the Secretary of ORSA, of a formal application accompanied by a lis of members and a reasonable constitution. These having been received, the Section is considered established.

The Section will be organized along the lines of the Transportation Science Section. The Council of the Section will be composed of the Section Chairman, Vice-Chairman, Secretary, and Treasurer, the two past Chairmen most recently retired from office, and three elected Councilmen.

All members of ORSA may qualify for membership in the Cost-Effectiveness Section by signifying their intent to join to the officers of the Section. Since the Section is nationwide, there will be no dues.

The Object of the Section, as identified in the By-Laws of the Section, is as follows: "The object of the Cost-Effectiveness Section shall be to develop a universally-acceptable set of norms and terminology for cost-effectiveness and to promote the development of new concepts, procedures, techniques, and algorithms for application to systems costing, systems effectiveness, and the scientific treatment of interactions between cost and effectiveness considerations. In pursuing this object, the Cost-Effectiveness Section will promote understanding and dissemination of information about cost-effectiveness, and will strive to enhance the knowledge of Section members about cost-effectiveness."

The By-Laws have been approved by the fifty-one charter members and an *ad hoc* nominating committee is in the process of preparing a candidate slate of officers. Elections will be held in the Spring of 1965 Pending the election of officers, membership inquiries may be sent to: MR. JOHN W. LOCKE, Booz, Allen Applied Research Inc., 4815 Rugby Avenue, Bethesda, Maryland 20014.

APPLICATIONS ISSUE OF *OPERATIONS RESEARCH*

The Publications Committee of ORSA has invited the Washington Operations Research Council (WORC) to edit an issue of *Operations Research,* to be devoted exclusively to applications and case histories. Although the history of Lanchester Prize papers is heavily oriented to applications, the general literature gives a stronger methodological orientation; this issue is an experiment in determining whether there is a good supply of such papers, and whether there is a real demand for them.

WORC has accepted the invitation, and has named W. EDWARD CUSHEN as *Guest Editor* for the issue. He will work with a WORC Editorial Board, and a group of Associate Editors. Papers will be reviewed in accordance with standards established for *Operations Research,* with the exception that ingenuity and success of applications will dominate criteria related to methodology. The WORC Editorial Board for this issue consists of ALFRED BLUMSTEIN, *WORC's President,* as *Chairman,* ED CUSHEN, MURRAY GREYSON, BOYD LADD, and WINSTON RILEY III.

We now look to the operations research community to demonstrate that sufficient good applications exist to justify such an outlet. We solicit applications papers to be published in this special issue, to be received by 31 July 1965. Manuscripts should be submitted to: DR. W. EDWARD CUSHEN, Institute for Applied Technology, National Bureau of Standards, Washington, D C. 20234

SOCIETY AUTHORS

At the request of ROBERT E. MACHOL, *Chairman, ORSA Publications Committee* (made by letter enclosure in the last issue of the *Bulletin*), ORSA authors were asked to submit for publication a bibliography of books which they had written. The book list available at press time is given below, arranged by senior author.

The reader will note two interesting features of this list. First, the range of topics covered by ORSA Authors, including edited volumes and chapters in edited books, is impressive. Second, the list is clearly not complete: many well-known works have not been included. The compilation was made from replies received by the Editor to the request made, and no attempt has been made to duplicate existing bibliographic materials. Authors who did not respond have not been included in the list below.

Additional listings received by August 1, 1965, will appear in the Fall, 1965, *Bulletin*. Mail listings to VAN COURT HARE, JR., *ORSA Bulletin*, 420 Lexington Ave., New York, New York 10017. Please use format shown below. Author addresses may be found in the current *ORSA Directory*.

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News and Announcements

JOINT ORSA AND TIMS MEETING, LOS ANGELES

The 12th Annual Joint Western Regional Meeting of The Institute of Management Sciences and Operations Research Society of American will be held at the Ambassador Hotel, Los Angeles, California, 29–30 April 1965. An extensive program is being prepared around the central theme of "Techniques for Modern Management." There is room for a limited number of additional papers. Abstracts should be sent to: DR. RAOUL J. FREEMAN, Program Chairman, ORSA-TIMS Meeting, THE RAND Corporation, 1700 Main Street, Santa Monica, California.

WASHINGTON OPERATIONS RESEARCH COUNCIL (WORC) NEWSLETTER

The September, 1964, issue of the *WORC Newsletter* described the educational offerings in operations research available in the Washington, D. C., area in a format similar to that used in announcing similar offerings at other Universities in The Spring, 1963, and Spring, 1964, issues of the ORSA *Bulletin*. WORC Secretary is DR. JOHN HONIG, *% Honeywell Company, 1701 Pennyslvania Avenue, Washington, D. C.* WORC dues are $4.00 per year from September 1, annually.

ECONOMICS OF AUTOMATIC DATA PROCESSING (ROME)

The *International Computation Centre* (ICC) will hold a Symposium on the Economics of ADP. A call for papers to be sent to "Symposium on Economics of ADP," International Computation Centre, Casella Postale No. 10053, *EUR-ROME*, Italy, has been made. Closing data for submission was April 30, 1965. The Symposium will be held in Rome in October, 1965.

OCEAN SCIENCE AND OCEAN ENGINEERING

Ocean Science and Ocean Engineering Conferences and Exhibit will be held June 14–17, 1965, at the Washington Hilton Hotel, Washington, D. C. This is the first national conference to explore the role of marine technology to utilize the resources of the sea and the marine environment. For more information, contact RADM. M. H. SIMONS, JR., *Executive Secretary, Marine Technology Society, 1030 15th St., N.W., (Suite 828), Washington, D. C. 20005.*

BUSINESS INTELLIGENCE CONFERENCE

The Proceedings of the 1964 Conference on Modern Business Intelligence Systems, held in Los Angeles California, (1964), may be obtained from R. M. Greene & Associates, 11691 National Boulevard, Los Angeles, California 90064, for $12.50, postpaid. The work includes nine articles.

INTERNATIONAL SYMPOSIUM ON MULTIVARIATE ANALYSIS

It is planned to hold an International Symposium on Multivariate Analysis at the University of Dayton, Ohio during the period June 14–19, 1965. This symposium is sponsored by the Aerospace Research Laboratories (ARL) at Wright-Patterson Air Force Base, Ohio. ARL is a unit of the Office of Aerospace Research, the research agency of the United States Air Force. PROFESSOR HAROLD HOTELLING has accepted the invitation to deliver the Inaugural Address. Attendance at the symposium is open to anyone interested. Further information may be obtained from DR. P. R. KRISHNAIAH (organizer), *Research Mathematical Statistician, Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio, U. S. A.*

FIRST INTERNATIONAL CONFERENCE ON PROGRAMMING AND CONTROL

The First International Conference on Programming and Control was held at the United States Air Force Academy, Colorado Springs, Colorado, April 15–16, 1965.

For further information write to PROFESSOR G. B. DANTZIG, *Operations Research Center, University of California, Berkeley, California.*

AMERICAN SOCIETY FOR CYBERNETICS

The American Society for Cybernetics held its Inaugural Dinner on October 16, 1964, at the Cosmos Club, Washington, D. C. The Inaugural Dinner Chairman was DR. FRANK FREMONT-SMITH, New York Academy of Sciences.

Introductory remarks were made by PAUL S. HENSHAW, Chairman *pro tem.* The program consisted of talks on cybernetics with discussions on *MAN* by DR. WARREN MCCULLOCH, M.I.T.; *MACHINES* by DR. JULIAN BIGELOW, I.A.S.; and *SOCIETIES* by DR. F. S. C. NORTHROP, Yale University.

Honorary founders of the American Society for Cybernetics attended the dinner along with honored guests and representatives from the following Societies and Associations:

American Iron and Steel Institute
Institute of Management Sciences
Association of American Railroads
Association for Computing Machinery
Business Equipment Manufacturers Association
American Mathematical Society
Operations Research Society of America

For further information write to the:

American Society for Cybernetics
1303 Wisconsin Avenue, N.W.
Washington, D. C.

RUTGERS SUMMER O.R. COURSE

The Industrial Engineering faculty of the Mechanical Engineering Department of Rutgers—The State University announces a two-week intensive course on Operations Research in Industry, to be offered during the period June 7–18, 1965. This program is primarily designed for experienced graduate engineers who wish to gain an understanding of the modern methods of Operations Research and their applications to industrial problems.

The course will emphasize the meaningful solution of problems in production and inventory control, allocation of resources, and other areas of interest to industry (marketing, administration, etc.). Specific illustrations from actual industrial practice will be presented.

Methods to be covered include such topics as linear, non-linear, and dynamic programming; inventory with constant and probabilistic demands; demand forecasting; marketing competition; queuing, simulation of random processes; reliability; and job scheduling and sequencing.

Several computer programs for the IBM 1620 and the IBM 7040 have been specially developed or adapted for this course. The computational facilities available at the Rutgers Center for Information Processing will be used to illustrate the actual solution of medium and large scale operations research problems.

For Further Information Contact:

PROFESSOR ANTHONY J. DEL MASTRO
Director Continuing Engineering Studies
Rutgers—The State University
College of Engineering
New Brunswick, New Jersey 08903

UNIVERSITY OF MICHIGAN SUMMER COURSES

The University of Michigan will hold its usual summer courses in operations research. This summer the courses are: Foundations and Tools for Operations Research and the Management Sciences, August 9–20, $275; Operations Research Problems in Engineering, August 9–20, $275; Recent Mathematical Advances in Operations Research and Management Sciences, August 9–20, $275; Quality Control by Statistical Methods, August 9–19, $200; Applications of Computers in Hospital Management, June 21–25, $160. For complete information write: *Engineering Summer Conferences, West Engineering Building, University of Michigan, Ann Arbor, Michigan.*

UNIVERSITY OF MICHIGAN PROGRAM IN O.R.

The Graduate School at the University of Wisconsin has approved the formation of a University-wide Committee on Operations Research and Administrative Science. The members are Professors NADLER, *Chairman* (Industrial Engineering), BAWDEN (Agricultural Economics), BOX (Statistics), FAGEN (Urban and Regional Planning), GAUMNITZ (Commerce), HAGE (Sociology), HOLT (Economics), JAMES (The University of Wisconsin-Milwaukee), KARREMAN (Mathematics Research Center), MORTON (The University of Wisconsin-Milwaukee), PENNIMAN (Political Science), ROSEN (Computer Science), and RUDD (Chemical Engineering).

Operations Research is frequently said to concern the quantitative formulation and solution of decision problems including the design of decision and control systems. Administrative Science is said to concern the human organization which defines the problems and operates the systems. A significant philosophy about the Operations Research and Administrative Science (ORAS) program at The University of Wisconsin is that attention to *both* areas is considered essential.

Since both the techniques of analysis and the knowledge of substantive areas are treated in various departments throughout the University. The ORAS Committee will coordinate work in this area.

As a start, the committee administers an interdisciplinary minor in ORAS for the PhD. Students who take the minor will come from a variety of different backgrounds and may be majoring in any one of a number of different areas. He will select an area of application and choose the tools of analysis that are particularly relevant, or he may concentrate on a tool of analysis and study applications in various areas. The committee seeks to retain flexibility to insure that the minor course of approved study will provide an intellectual challenge in ORAS and will enrich and broaden the particular student. To achieve this. each student's program will be considered individually in consultation with his major professor and must be approved by the chairman or executive group of the ORAS committee.

The candidate should have introductory preparation satisfactory to the committee. An ideal background would include introductory courses in statistics, differential and integral calculus, matrix algebra, computer programming, and some social science courses, economics, political science and sociology that stress organization behavior. Because many suitable students will not have this ideal background, all interested students are urged to consult the chairman of the committee.

The minor program must provide a minimum of 12 credits. Three credits are chosen from each of the following three areas except that the courses must be taught outside of the sutdent's major department or school:

1—Probability Theory and Statistical Inference
2—Optimization Techniques
3—Administrative Sciences

Where the student's major program of study already includes such courses, other courses outside his major field should be substituted. Students whose major program is strong in quantitative tools are urged for their minor to select courses in the administrative science area and vice versa.

The additional three credits will be an integrating course, *Problem Seminar in Operations Research and Administrative Sciences,* to be taken as the last one in the minor sequence. The course will involve lectures regarding the unifying concepts of systems, a weekly laboratory to review applications of ORAS within a disciplinary and interdisciplinary framework, and an individual project for each student to provide insight to the breadth of problem solving in ORAS.

UNIVERSITY OF WISCONSIN OFFERS INTENSIVE COURSE IN WORK DESIGN

An intensive course in Work Design will be presented by The University of Wisconsin Extension Division in cooperation with the College of Engineering and the local Chapters of American Institute of Industrial Engineering and Society for the Advancement of Management on June 7 through June 18, 1965.

The course covers the design of complete management systems in contrast to the casual "improvement" or "immediate problem solutions" approach. Among the topics to be considered in depth are concepts of systems, philosophy of work design, mathematical models, management policies for effecting change, development of manpower utilization, etc. Applications will be emphasized through the use of case studies presented by experienced personnel.

The staff includes many who are applying Work Design to various organizations. DR. LILLIAN M. GILBRETH will give the keynote address. The course is under the supervision of DR. GERALD NADLER, originator of the Work Design program, author of a book on Work Design and organizer of the first education courses on Work Design in the United States and England.

For additional information and a descriptive borchure write to: *Engineering Institutes, The University of Wisconsin Extension Division,* Attention: W. W. WUERGER, *432 North Lake Street, Madison, Wisconsin 53706.*

OPERATIONS RESEARCH OPPORTUNITIES IN MATHEMATICS

The Division of Mathematics, National Academy of Sciences—National Research Council, calls attention to a variety of fellowships and other support for basic research in mathematics. Sources of support are given in the bulletin "A Selected List of Major Fellowship Opportunities and Aids to Advanced Education," available from the Fellowship Office, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, N.W., Washington, D. C. 20418.

NATIONAL ACADEMY OF SCIENCE GRADUATE AND POSTDOCTORAL FELLOWSHIPS 1965–6

The National Academy of Sciences-National Research Council has been called upon again to advise the National Science Foundation in the selection of candidates for the Foundation's program of *graduate* and *regular postdoctoral* fellowships. Committees of outstanding scientists appointed by the Academy-Research Council will evaluate applications of all candidates. Final selection will be made by the Foundation, with awards to be announced on March 15, 1965.

Fellowships will be awarded for study in the mathematical, physical, medical, biological and engineering sciences; also in anthropology, economics (excluding business administration), geography, the history and philosophy of science, linguistics, political science, psychology (excluding clinical psychology), and sociology (not including social work). They are open to college seniors, graduate students working toward a degree, postdoctoral students, and others with equivalent training and experience. All applicants must be citizens of the United States and will be judged solely on the basis of ability.

Applicants for the graduate awards will be required to take the Graduate Record Examinations designed to test scientific aptitude and achievement. The examinations, administered by the Educational Testing Service, will be given on January 16, 1965, at designated centers throughout the United States and certain foreign countries.

The annual stipends for graduate Fellows are as follows: $2400 for the first level; $2600 for the intermediate level; and $2800 for the terminal level. The annual stipend for postdoctoral Fellows is $5500. Limited allowances will also be provided to apply toward tuition, laboratory fees, and travel.

Further information and application materials may be obtained from the Fellowship Office, National Academy of Sciences-National Research Council, 2101 Constitution Avenue, N.W., Washington, D. C. 20418.

JOINT COMPUTER CONFERENCE AWARDS PRIZE

DR. DAVID N. FREEMAN, a member of ORSA, was recently awarded a prize for the most significant paper presented at the 1964 Fall Joint Computer Conference. His paper on *Error Correction in CORC* was based upon his doctoral thesis at Cornell University in the Field of Industrial Engineering and Operations Research. The thesis work was directed by PROFESSORS R. W. CONWAY and W. L. MAXWELL and was the outgrowth of a Cornell University sponsored project to develop a computer language appropriate for use in undergraduate engineering education. DR. FREEMAN is currently at the Endicott Laboratories of the International Business Machines Corporation.

PROGRAM OF VISITING LECTURERS IN STATISTICS

With the financial support of the National Science Foundation, a Visiting Lecturer Program in Statistics is being jointly sponsored by the principal statistical organizations of the country, the *American Statistical Association, Biometric Society,* and *Institute of Mathematical Statistics.*

The program has five objectives: (1) to provide education, (2) establish and emphasize the rôle statistics plays in research and practice, (3) to create awareness of career opportunities, (4) to provide advice and information to students, and (5) to encourage and stimulate new programs in statistics (at Educational Institutions and elsewhere).

Brochures describing the program's operation were mailed to colleges throughout the U. S. in August (1964). Institutions not receiving the brochure or requiring further information should write PROFESSOR J. KEIFER, *Department of Mathematics Cornell University, Ithaca, New York.*

THE AMERICAN SOCIETY FOR CYBERNETICS INAUGURAL DINNER

The American Society for Cybernetics held its Inagural Dinner on October 16, 1964, at the Cosmos Club, Washington, D. C. The Inaugural Dinner Chairman was Dr. Frank Fremont-Smith New York Academy of Sciences.

Introductory remarks were made by Paul S. Henshaw, Chairman pro tem. The program consisted of talks on cybernetics with discussions on MAN by Dr. Warren McCulloch, MIT; MACHINES by Dr. Julian Bigelow, IAS; and SOCIETIES by Dr. F. S. C. Northrop, Yale University.

Honorary founders of the American Society for Cybernetics attended the dinner along with honored guests and respresntatives from the following Societies and Associations:

American Iron and Steel Institute

Institute of Management Sciences
Association of American Railroads
Association for Computing Machinery
Business Equipment Manufacturers Association
American Mathematical Society
Operations Research Society of America

For further information write to the:

American Society for Cybernetics
1303 Wisconsin Avenue, N.W.
Washington, D. C.

WORC LECTURE PROGRAM

The WASHINGTON OPERATIONS RESEARCH COUNCIL has announced a ten-lecture program directed at military and civilian staff members. The lectures will start on 10 May and are scheduled each Monday and Wednesday thereafter with the concluding session on 9 June.

For further information contact E. P. VISCO, RAC, McLean, Va. 22101, telephone 703-893-5900, ext. 316.

M.I.T. COURSES

The Massachusetts Institute of Technology announces a two-week course entitled "Methods of Operations Research" to be given August 30 through September 10, 1965 for interested and qualified persons. The course will be under the direction of PROFESSOR GEORGE P. WADSWORTH, assisted by M.I.T. faculty and staff of the M.I.T. Operations Research Center.

M.I.T. will also offer a summer course entitled "Design and Analysis of Scientific Experiments," July 12–July 23, 1965. Lectures will be given by PROFESSOR HAROLD FREEMEN.

"Operations Research in Marketing," is the title of another M.I.T. summer offering under the direction of PROFESSOR JOHN D. C. LITTLE of the Sloan School.

Detailed information may be obtained by writing the *Summer Session Office, Massachusetts Institute of Technology, Daggett Building, Room E19-356, Cambridge, Mass. 02139.*

CANADIAN OPERATIONAL RESEARCH SOCIETY

The Seventh Annual Conference of CORS will be held in Toronto, Canada, at the University of Toronto on May 13 and 14, 1965. Information about the program and details on registration and arrangements can be obtained from P. T. TAYLOR, % Lever Brothers Limited, 299 Eastern Avenue, Toronto 8, Ontario, Canada.

PERSONAL ITEMS

REYNOLD GREENSTONE has joined Ordnance Research Laboratory, Pennsylvania State University, State College, Pennsylvania, 16801.

ROBERT S. TRIPLETT has joined the faculty of The George Washington University, Washington, D. C.

William Grodowitz has recently been promoted within Hq USAF to the position of Special Assistant for Program Evaluation, Directorate of Aerospace Programs.

John E. Vavasour has been named Director of Corporate Systems and Procedures for American Metal Climax, Inc.

Leon W. Cohen, on leave from his post as Chairman of the Department of Mathematics of the University of Maryland, has succeded M. H. Martin as Executive Secretary of the Division of Mathematics, National Academy of Sciences.

Robert J. Schreiber has joined the Corporate Research Group of Time, Inc., New York City.

Daniel Teichroew has been appointed Head of Organizational Sciences at Case Institute of Technology, Cleveland, Ohio.

Donald E. Cleveland recently joined the faculty of Civil Engineering in the School of Engineering and Applied Science of the University of Virginia.

Clarence W. Little, Jr., has been named Vice President in charge of Research and Development at the Waukesha Foundary Company, Waukesha, Wisconsin.

Paul D. Birkhahn has been appointed Director, Operations Research, for Pennsylvania Research Associates, Philadelphia, Pennsylvania.

Donald Gross has been appointed Assistant Professor of Engineering and Applied Science, the George Washington University, Washington, D. C.

R. William Rae, has been appointed Director of the Research Analysis Corporation's (RAC) office in Bangkok.

Marshall Andrews of RAC has retired, and has been appointed RAC consultant.

Philip R. Compton has been appointed Planning Manager of RAC.

Sherwood C. Frey has joined the Center for Naval Analysis of the Franklin Institute (CNA).

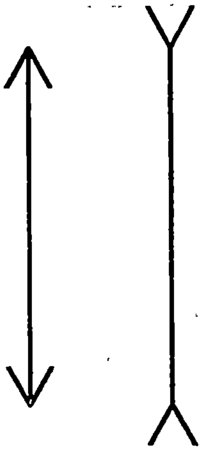
Leslie R. Heselton, Jr. has joined CNA.

J. P. Ruina has been elected President of the Institute for Defense Analysis (IDA). Dr. Ruina succeeds Richard M. Bissell, Jr.

James E. Cross has been elected to the position of Secretary of IDA.

Fordyce E. Tuttle has been elected to the Board of Directors of Operations Research Incorporated (ORI). The following have joined ORI, according to recent releases: Robert J. Gauntt, James T. Barbera, Harry A. DeFerrari, Philip Cheilik, Don J. Farquhar, John Horowitz, Jerry E. Haney.

Ken-ichi Koyanagi, *Managing Director and Founder* of the Japanese Union of Scientists and Engineers, and a *Member* of the Operations Research Society of America, has passed away. John E. Walsh, *ORSA Treasurer*, has extended the condolences of the Society to the Japanese Union of Scientists and Engineers and to the operations research community of Japan in a recent letter to T. Takamatsu, *Assistant Managing Director* of the Japanese Union.



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MANUSCRIPTS for publication and Letters to the Editor should be submitted to the Editor of the SOCIETY, either directly or through one of the Associate Editors. Each MS is in general sent to two referees, and from two to four months are ordinarily required for this refereeing process. If a paper is submitted to an Associate Editor, he will arrange to have it refereed before forwarding it to the Editor.

Manuscripts must be double-spaced throughout (including abstract, footnotes, subsidiary matter, tables, and references), with the original in typewritten or equally legible form. Furnishing a complete, legible, duplicate copy accelerates the process of refereeing, but is not mandatory. The style of the JOURNAL should be meticulously followed in copy preparation.

References should be numbered consecutively and grouped at the end of the paper; for journal references give at least author, volume, page, and year; for book references give at least author, title, publisher, city, and year.

In mathematical expressions, authors are requested to use the solidus whenever possible in preference to built-up fractions, to write complicated exponentials in the form exp( ), to avoid subscripts or superscripts *on* subscripts or superscripts, and in general to minimize unusual or expensive typographical requirements. Subscripts and superscripts must be shown large and clear; Greek letters and unusual symbols should be labeled on first occurrence, as should subscript 'zero,' to distinguish it from 'oh.' Whether each letter is capital or lower case must be unambiguous. Equation numbers must be *at the right.*

Figures must be drawn in black ink on white paper in a form suitable for photographic reproduction. Lettering must be of uniform size and sufficiently large to be legible when the figure is reduced to final size. Figures should be designated by arabic numbers, and legends for all figures must be typed on a single separate sheet rather than placed on the drawings.

Material that has already been published in books or recognized journals, or submitted for such publication elsewhere, is *not* acceptable for publication, but *review articles*, so labeled, are solicited.

Each article representing original research must be accompanied by an *Abstract* of from 100 to 200 words, to be printed at the head of the article. The abstract should summarize the principal results and conclusions. Articles representing original research should be kept as brief as possible, consistent with clarity; arguments already available in other published work should be merely cited, not repeated; references to related previous work should be reasonably complete.

Manuscripts not conforming closely to the above instructions will not be refereed or considered for publication until suitable copy is furnished.

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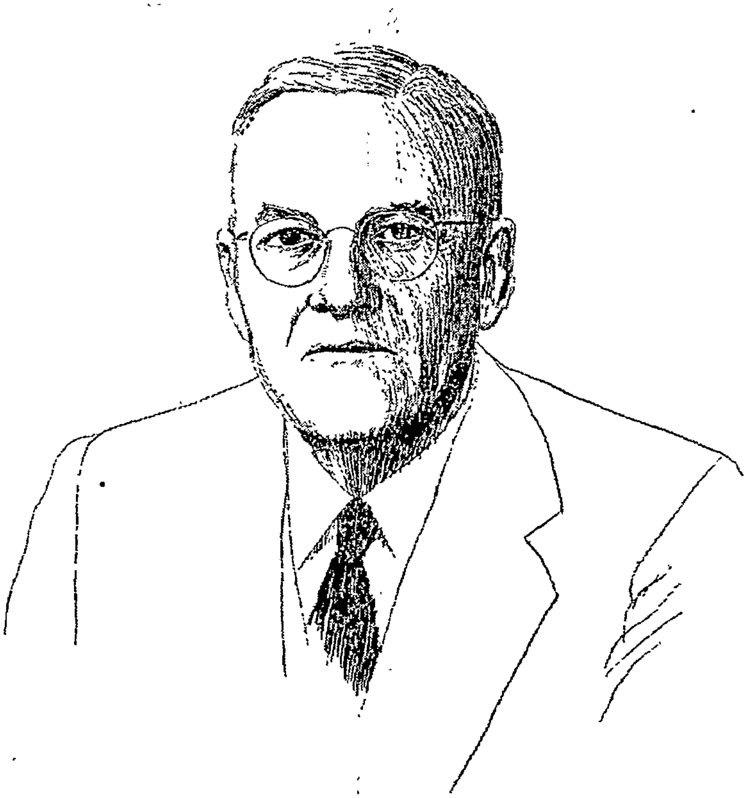

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Ironically, it was also the deadline, set forth in an ultimatum six months earlier by Nikita Khrushchev, for the West to get out of Berlin. But because Dulles had stood firm—as he had in so many earlier showdowns between Western determination and Communist expansionism—May 27, 1959 was a carefree spring day in Berlin, nothing more, nothing less.

Dulles, often stressing that peace is not to be had simply for the wanting, fought all his life for a just and moral peace, a peace founded on interdependence of nations and the dignity of man. We have not yet achieved his objectives. But time has both vindicated his judgment and affirmed the remarkable breadth of his accomplishment.

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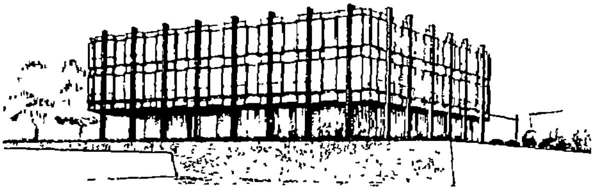

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IT IS THE POLICY OF OPERATIONS RESEARCH to select for publication papers whose content will be of interest to at least a significant group of members of the SOCIETY. The content should be substantial, rather than trivial, and should detail *methods*, as well as reporting *results*. Worthy contributions of less than substantial content, and short notes, should appear in the form of Letters to the Editor.

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1. Does this paper make a new and substantial contribution to the literature of operations research?
2. Is it an original contribution to methodology, a case history, a review, or a discussion? Is its character clear from title and text?
3. Is sufficient introductory and summary material given to inform any type of reader of the content, importance, and field of applicability of the material covered?
4. Is it clearly, precisely, and logically written? Are there any errors? Could it benefit from condensation or expansion? Give details.
5. Is adequate credit given to other contributors in the field and are references sufficiently complete? Please supply any significant omissions.
6. Do you recommend that it be published in OPERATIONS RESEARCH? If in your opinion it is not acceptable for publication in OPERATIONS RESEARCH, can you include changes to make it acceptable? As a paper or as a Letter to the Editor? Or is it more suitable for another journal? Or not worthy of publication?
7. Have you any reservations that make you feel that the judgment of another referee should be obtained? If so, please suggest a suitable person, or take the initiative in getting comments from some of your colleagues.

The Editor would appreciate receiving an unsigned carbon of your comments, suitable for transmission to the author. Your identity will not be revealed unless you request the Editor to do so because you would be interested in having the author communicate with you directly. Your comments should be as constructive as possible to assist the author and the JOURNAL in achieving a high standard of quality. In order to avoid delay in processing this MS, please try to return it with your comments within thirty days.

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Volume 60 Number 309

March 1965

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JOURNAL OF THE INSTITUTE OF MANAGEMENT SCIENCES

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Editor-in-Chief: Professor R. M. Thrall, University of Michigan

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The first issue of this journal was published in November 1952 and contained 32 pages of text. Started as a quarterly, it became a bi-monthly in 1956. Issues now average better than 170 text pages and the distribution is over 6500 copies per issue. The subscription for OPERATIONS RESEARCH is included in the annual dues of members. The current non-member subscription price is $10.00 per volume ($7.50 per volume outside U.S. and Canada) and back issues are available at $2.00 each.

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1965–1966

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Supplement 2 **OPERATIONS RESEARCH** **Volume 13, 1965**

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The Houston Meeting

REGISTRATION INFORMATION

Registration

The registration desk will be located in the lobby of the Shamrock Hilton Hotel. The registration desk will be open during the following hours:

Wednesday, November 3	6:30 PM to 9:00 PM
Thursday, November 4	8:00 AM to 5:00 PM
Friday, November 5	8:00 AM to 5:00 PM

Those who have pre-registered may pick up registration card and tickets to the meal events at the registration desk.

For those who have not pre-registered, the fees will be as follows:

ORSA Member	$12.00
Non-Member	$14.00
Student	$2.00
Thursday	
Buffet	$4.00
Banquet	$7.50
Friday	
Luncheon	$4.00

Accommodations

The Shamrock Hilton Hotel has reserved a block of rooms for the meeting attendees. All meetings and functions will be held in the Hotel. Room reservations must be made directly with the hotel. Room rates are: Single, $9–18; Doubles, $13–22; Twin, $14–24; Parlor, $25 up.

CONCEPT OF THE PROGRAM

Operations Research for Social and Economic Profit

The primary goal of Operations Research is the maximization of profit. The precise definition of profit has long been a problem to Operations Research practitioners. When the diverse fields of Operations Research are considered, "profit" must be defined in a larger sense. This meeting will present the profit motive and Operations Research in this contemporary context. Most of the application sessions are business oriented, although several are not. The importance of National Defense as one requirement to assure our continued opportunity to pursue the business profit motive is recognized. Two sessions are devoted to this subject. Sessions are organized on two of the techniques which have been most successful in enhancing profitability: PERT-CPM and Mathematical Programming. One session is devoted to Space Missions—an area that has profit promise in the scientific sense as well as in National Defense.

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A-1 OR in Banking and Finance
Dr. C. Jackson Grayson, Jr., *Tulane University.*
A-2 OR in the Process Industries
Dr. Robert B. Grant, *Celanese Corporation.*
A-3 OR in National Security
Dr. George E. Kimball, *Arthur D. Little, Inc.*
B-1 Corporate Modeling and Simulation
Mr. George M. Brooks, *Bonner and Moore Associates, Inc.*
B-2 OR in Transportation
Dr. Robert M. Oliver, *University of California, Berkeley.*
B-3 OR in Space Missions
Mr. Harold E. Gartrell, *Manned Spacecraft Center, NASA.*
B-4 Mathematical Models of Combat (Panel)
Mr. Ervin Kapos, *Center For Naval Analyses.*
C-1 Profit-Oriented Uses of Operations Research
Mr. L. Duvall Webster, Jr., *Sunray DX Oil Company.*
C-2 PERT-CPM: Basic Review and Systems
Dr. A. W. Wortham, *Texas A&M University.*
C-3 Techniques for Solving Large-Scale Mathematical Programs
Dr. A. C. Williams, *Socony Mobil Oil Company.*
D-1 OR: An Effective Aid in Municipal Planning
Mr. Hayward Lane, *Profit Development and Controls Corp.*
D-2 PERT-CPM: Recent Applications and Techniques
Dr. A. W. Wortham, *Texas A&M University.*
D-3 Special Applications and Techniques in OR
Mr. J. T. Dwyer, *Ernst & Ernst.*
D-4 Algorithmic Extensions to Operations Research Theory
Dr. Arnold E. Saffer, *Humble Oil and Refining Co.*

SYNOPSIS OF THE HOUSTON MEETING

Session	Event	Room	Time
	Thursday, November 4		
A-1	OR in Banking and Finance	EMERALD	8:30–12:00
A-2	OR in the Process Industries	GRECIAN	
A-3	OR in National Security	CASTILLIAN	
Buffet Luncheon		CONTINENTAL	12:00–1:15
B-1	Corporate Modeling and Simulation	EMERALD	1:30–5:00
B-2	OR in Transportation	GRECIAN	
B-3	OR in Space Missions	CASTILLIAN	
B-4	Mathematical Models of Combat; Military Applications Section Meeting	CONTINENTAL	
Social Hour		CONTINENTAL	6:30–7:30
Banquet		CONTINENTAL	7:30
	Speaker—ASTRONAUT DONN F. EISELE		
	Friday, November 5		
C-1	Profit-Oriented Uses of Operations Research	EMERALD	8:30–12:00
C-2	PERT-CPM: Basic Review and Systems	GRECIAN	
C-3	Techniques for Solving Large-Scale Mathematical Programs	CASTILLIAN	
Luncheon		CONTINENTAL	12:00–1:15
	Speaker—DR. GEORGE E. KIMBALL, *Arthur D. Little, Inc.*		
D-1	OR: An Effective Aid in Municipal Planning	EMERALD	1:30–5:00
D-2	PERT-CPM: Recent Applications and Techniques	GRECIAN	
D-3	Special Applications and Techniques in O.R.	CASTILLIAN	
D-4	Algorithmic Extensions to Operations Research Theory	CONTINENTAL	

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PROGRAM

of the

TWENTY-EIGHTH NATIONAL MEETING

of the

OPERATIONS RESEARCH SOCIETY OF AMERICA

THURSDAY MORNING, NOVEMBER 4 EMERALD ROOM

Session A-1: 8:30–12:00

O.R. in Banking and Finance

Chairman: DR. C. JACKSON GRAYSON, JR.
Tulane University, New Orleans, Louisiana.

A-1.1*Analytical Methods in Banking, KALMAN J. COHEN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

A-1.2*Adventures in ORBIT (Operations Research in Banking, Investments and Trusts), ROBERT L. KRAMER, *Bankers Trust Company, 16 Wall Street, New York, New York.*

A-1.3*Application of Linear Programming to the Choice of a Capital Structure, WILLIAM BERANEK, *Professor of Commerce, University of Wisconsin, Madison, Wisconsin.*

A-1.4*On the Simulation of Investment Behavior, GEOFFREY P. E. CLARKSON, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

A-1.5 Loan Operation Profit Maximization Through OR, FREDERICK B. CORNISH, *Ernst & Ernst, Fidelity-Philadelphia Trust Bldg., Philadelphia, Pennsylvania 19109.*

A-1.6 An Application of Heuristic Problem Solving to Accounts Receivable Management, FERDINAND K. LEVY, *Dept. of Economics and Business Administration, Rice University, Houston, Texas.*

A-1.7 Scheduling Branch Pickups and Deliveries, DONALD B. BROUT, *Arthur Young & Company, 277 Park Avenue, New York, New York 10017.*

* Invited paper.

THURSDAY MORNING, NOVEMBER 4 GRECIAN ROOM

Session A-2: 8:30–12:00

O.R. in the Process Industries

Chairman: DR. ROBERT B. GRANT
Celanese Corporation, 522 5th Avenue, New York, New York 10036.

A-2.1***Plant Investment Problem,** NEAL CLEARY, *Phillips Petroleum Co., Bartlesville, Oklahoma.*

A-2.2***On Implementing Operations Research in a Decentralized Company,** WILLIAM R. DAVISON, *Standard Oil Company (Indiana), 910 South Michigan Avenue, Chicago, Illinois.*

A-2.3***The Profit Contribution of Linear Programming to the Management of Forest Industries,** C. G. EDGE, *Chemcell (1963) Limited, 1155 Dorchester Blvd. West, Montreal 2, Quebec, Canada.*

A-2.4***An Optimal Plant Location Study,** W. G. WELTER, *34 Hillcrest, Ponca City, Oklahoma.*

A-2.5 **Optimal Digital Control of a Chemical Reactor,** GEORGE L. NEMHAUSER, *Johns Hopkins University, Baltimore, Maryland and* MICHAEL E. THOMAS, *University of Florida, Gainsville, Florida.*

A-2.6 **Towards an Automated 'Total' Information System,** S. RAY ADKINS, *The Mead Corporation, Dayton, Ohio and* JOHN F. PIERCE, *IBM Systems Research and Development Center, Cambridge, Massachusetts.*

THURSDAY MORNING, NOVEMBER 4 CASTILLIAN ROOM

Session A-3: 8:30–12:00

O.R. in National Security

Chairman: DR. GEORGE E. KIMBALL
Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts 02104.

A-3.1 **BRAT (Acronym for BRanching Analysis Technology): an Approach to System Definition, Synthesis, and Effectiveness Assessment,** R. R BOYCE, and E. V. BRUCHEZ, *Martin Company, Orlando, Florida.*

A-3.2 **Weapon Allocation for Fallout Attacks,** FLOYD I. JOHN, *Stanford Research Institute, Menlo Park, California and* JOHN W. ULRICH, *Stanford Research Institute, Menlo Park, California.*

A-3.3 **A Damage-Limiting Shelter-Allocation Strategy,** GRACE J. KELLEHER, *Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia 22202.*

A-3.4 **The Effect of Monitoring System Performance on Force Effectiveness,** JAY W. MILLER, *The Boeing Company, Aero-Space Division, Seattle, Washington.*

A-3.5 **An Analytical Solution For Periodic Maintenance of a System,** JAMES F. DAUGHTRY, III, *The Bunker-Ramo Corporation, 8433 Fallbrook Avenue, Canoga Park, California 91304.*

A-3.6 **Kill Probability Model for Multiple Dependent Shots,** G. L. GALLAGHER, *Autonetics, 3370 Miraloma Avenue, Anaheim, California.*

A-3.7 **Modeling the Civilian and Military Manpower Environment in the 65–74 Era,** G. BERNSTEIN, *Research Analysis Corp., McLean, Virginia and* H. SAFEER, *Research Analysis Corp., McLean, Virginia.*

A-3.8 **The Cost/Effectiveness of Reenlistment Incentives in the Navy—A Simulation Study,** ANTON S. MORTON, *Institute of Naval Studies, Center for Naval Analyses, 545 Technology Square, Cambridge 39, Massachusetts and* FRANKLIN M. FISHER, *Department of Economics, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.*

A-3.9 **Nuclear Cost Assessment Technique (NUCAT),** CARLTON COMBS JR., DAVID C. BROWN and RICHARD D. CUTHBERT, *Combat Operations Research Group, P.O. Box 116, Ft. Belvoir, Virginia.*

A-3.10 **Vulnerability Influence on Cost Effectiveness of Tactical Airborne Vehicles,** R. W. ALLEN, *Douglas Aircraft Company, Inc., Santa Monica, California.*

THURSDAY NOON, NOVEMBER 4 CONTINENTAL ROOM

Buffet Luncheon

12:00–1:15

THURSDAY AFTERNOON, NOVEMBER 4 EMERALD ROOM

Session B-1: 1:30–5:00

Corporate Modeling and Simulation

Chairman: MR. GEORGE M. BROOKS
Bonner and Moore Associates, Inc., 500 Jefferson Building,
Houston, Texas 77002.

B-1.1*Corporate Model for Steel Production, W. O. BLATTNER, *United States Steel Corporation, Pittsburgh, Pennsylvania.*

B-1.2*A Refinery and Distribution Planning System, JACK M. GILLETTE, *Bonner and Moore Associates, Inc., 500 Jefferson Building, Houston, Texas 77002.*

B-1.3*PDP—A Broad Spectrum Planning and Control System, CHARLES LEWIS, *General Mills, Minneapolis, Minnesota.*

B-1.4*Non-linear Distribution Problems, B. R. BUZBY, *Management Services Department, Union Carbide Corporation, 270 Park Avenue, New York, New York 10017.*

B-1.5 A Practical Simulation of Corporate Financial Operations or CORBUS, FREDERICK B. CORNISH, *Ernst & Ernst, Fidelity-Philadelphia Trust Bldg., Philadelphia, Pennsylvania 19109.*

B-1.6 International Market Distribution Simulation Model, C. H. CHYUNG, *Int'l Minerals & Chemical, Skokie, Illinois 60078.*

B-1.7 Drawing Valid Conclusions from Corporate Simulations, MALCOLM H. GOTTERER, *Pennsylvania State University, University Park, Pennsylvania 16802.*

THURSDAY AFTERNOON, NOVEMBER 4 GRECIAN ROOM

Session B-2: 1:30–5:00

O.R. in Transportation

Chairman: DR. ROBERT M. OLIVER
University of California, Berkeley, California.

B-2.1 **Peak-Period Analysis and Control of a Freeway System,** JOSEPH A. WATTLEWORTH, *Texas Transportation Institute, Texas A&M University, College Station, Texas.*

B-2.2 **The Effect of Driver Response-Time on Throughput at a Saturated Signalized-Intersection,** C. J. ANCKER, JR. *and* A. V. GAFARIAN, *System Development Corporation, Santa Monica, California.*

B-2.3 **A Model for Simulating Inter-City Traffic Flows,** MARTIN J. ARONOFF *and* BERNARD M. LEVIN, *Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

B-2.4 **Individual Preferences for Various Means of Transportation,** FRANK BENSON *and* MILES MARTIN, *Dept. of Statistics and Operations Research, University of Pennsylvania, Philadelphia 4, Pennsylvania.*

B-2.5 **A Domination Theorem for Optimal Locations,** A. J. GOLDMAN *and* P. R. MEYERS, *National Bureau of Standards, Washington, D.C. 20234.*

B-2.6 **Transportation Science Section Meeting.**

THURSDAY AFTERNOON, NOVEMBER 4 CASTILLIAN ROOM

Session B-3: 1:30–5:00

O.R. in Space Missions

Chairman: MR. HAROLD E. GARTRELL
Manned Spacecraft Center, NASA, Houston, Texas.

B-3.1***On the Role of the Digital Computer in Planning Future Space Flight Programs,** STANLEY ROSS, *NASA, Washington, D.C.*

B-3.2***Use of Operations Research in Effective Planning of Space Missions and Space Programs,** C. B. MOORE *and* T. E. PEACE, *Operations Research Section, General Dynamics/Ft. Worth, Ft. Worth, Texas.*

B-3.3***Cost Effectiveness: Incentive Stimulant For Future Spacecraft Programs,** EDWARD D. LUPO, *MSC-NASA, Houston, Texas.*

B-3.4***Effective Design For Interplanetary Exploration via the Availability Concept,** ROY B. CARPENTER, JR., *North American Aviation, Downey, California.*

B-3.5 An Optimization Procedure Utilizing Dynamic Programming, W. H. PURCELL, JR., *Operations Research Section, General Dynamics/Ft. Worth, Ft. Worth, Texas.*

B-3.6 Application of Game Theory to Space Missions, VICTOR SELMAN, *Reliability & Operations Research, System Sciences Corporation, P.O. Box 1123, Falls Church, Virginia 22041.*

B-3.7 Budget Priority Analysis in Space Programs, MARK ALFANDARY-ALEXANDER, *Mathematics Branch, Operations Analysis, U. S. Atomic Energy Commission, Washington, D.C. 20545.*

THURSDAY AFTERNOON, NOVEMBER 4 CONTINENTAL ROOM

Session B-4: 1:30–5:00

Military Applications

Chairman: MR. ERVIN KAPOS

Center for Naval Analyses, 1401 Wilson Blvd., Arlington, Virginia 22209.

B-4.1 Mathematical Models of Combat-Panel (*Panel Members to be Announced*)

B-4.2 Military Applications Section Meeting

THURSDAY EVENING, NOVEMBER 4 CONTINENTAL ROOM

6:30–7:30

Social Hour

THURSDAY EVENING, NOVEMBER 4 CONTINENTAL ROOM

Banquet

Speaker—ASTRONAUT DONN F. EISELE

Subject: An Astronaut's Report on Space Missions

FRIDAY MORNING, NOVEMBER 5 EMERALD ROOM

Session C-1: 8:30–12:00

Profit-Oriented Uses of Operations Research

Chairman: MR. L. DUVALL WEBSTER, JR.
Systems and O.R., Sunray DX Oil Company, Tulsa, Oklahoma.

C-1.1 **Long Range Facilities Planning,** CHARLES F. KNIGHT, *Lester B. Knight & Associates, Inc., 549 W. Randolph Street, Chicago, Illinois.*

C-1.2 **Profit Contribution as a Means of Evaluating a Distribution System,** W. M. COHEN, *Price Waterhouse & Co., 60 Broad St., New York, N. Y. 10004.*

C-1.3 **LP Solution of a Manufacturing Problem,** E. E. MASON, *McDonnell Automation Center, P.O. Box 516, St. Louis, Missouri 63166.*

C-1.4 **Manufacture of a Product in the Face of Uncertain Demand,** PHILLIP G. CARLSON, *School of Business Administration, Tulane University, New Orleans, Louisiana, 70118.*

C-1.5 **A General Purpose Simulator for Forecasting Demand, Inventory Control and Production Scheduling,** N. BENCHKOVSKY, *Lybrand, Ross Bros. and Montgomery, 60 Broad Street, New York, N.Y. 10004.*

C-1.6 **Dynamic Programming Approach to Disposable-Reparable Inventory,** E. G. HURST, JR., *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

C-1.7 **Marketing Techniques and Corporate Modeling,** HENRI L. BEENHAKKER, *Stanford Research Institute, Menlo Park, California.*

C-1.8 **Maintenance Parts Logistics—A Simulation Approach,** S. FIELDEN, *International Business Machines Corporation, Field Engineering Division, Poughkeepsie, New York.*

C-1.9 **A Markovian Approach to Evaluating New Bank Services,** GERALD G. WISZ, *Marine Midland Corporation, 241 Main St., Buffalo, N. Y. 14203.*

C-1.10 **Profit Maximization in Incentive Contracts,** WILLIS A. SOPER, JR., *Raytheon Company, Bedford, Massachusetts.*

FRIDAY MORNING, NOVEMBER 5 GRECIAN ROOM

Session C-2: 8:30–12:00

PERT-CPM: Basic Review and Systems

Chairman: DR. A. W. WORTHAM
Industrial Engineering Department, Texas A&M University,
College Station, Texas.

C-2.1***Basic Review of PERT/CPM Technology (Tutorial Session),** GLEN SELF, *Industrial Engineering Department, Texas A&M University, College Station, Texas.*

C-2.2 A Unified Planning and Scheduling System, R. W. METZGER *and* R. E. THIELE, JR., *The Dow Chemical Company, Midland, Michigan.*

C-2.3 A Total Systems Approach to PERT-CPM, B. U. MILLER *and* D. E. MILLER, *Autonetics, Anaheim, California 92803.*

C-2.4 Networks for Multi-Project Operations, JOHN E. STACY, JR., *Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri.*

C-2.5 Project Scheduling with Limited Resources, JEROME D. WIEST, *Production Management Dept., University of California at Los Angeles, Los Angeles, California 90024.*

C-2.6 High-Speed Calculation of the Critical Paths of Large Networks, MICHAEL MONTALBANO, *IBM Systems Research & Development Center, 2670 Hanover Street, Palo Alto, California 94304.*

C-2.7 Automatic Computer PERT-CPM Plots, D. E. DALLIN, *University of Utah Computer Center, Salt Lake City, Utah.*

FRIDAY MORNING, NOVEMBER 5 CASTILLIAN ROOM

Session C-3: 8:30–12:00

Techniques for Solving Large Scale Mathematical Programs

Chairman: DR. A. C. WILLIAMS
Socony Mobil Oil Company, P.O. Box 1025, Princeton, New Jersey.

C-3.1*Solving Large-Scale Systems, GEORGE B. DANTZIG, *Operations Research Center, University of California, Berkeley, California.*

C-3.2*Computational Aspects of Large-Scale Quadratic Programming Problems, ANDREW WHINSTON, *University of Virginia, Charlottesville, Va.*

C-3.3*Applications of Column and Row Generating Techniques, RALPH E. GOMORY, *Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York.*

C-3.4*Delayed Data Generation: Experience and Prospects, RICHARD H. COBB, *Mathematica, Princeton, New Jersey.*

C-3.5 Finding Permutation Operations to Produce a Large Triangular Sub-Matrix, J. C. DICKSON, *Bonner & Moore Associates, Inc., 500 Jefferson, Houston, Texas 77002.*

C-3.6 Large Scale Nonlinear Programming, ANTHONY V. FIACCO, *Research Analysis Corp., McLean, Virginia and Northwestern University, Evanston, Illinois and* GARTH P. MCCORMICK *and* W. CHARLES MYLANDER, III, *Research Analysis Corp., McLean, Virginia.*

C-3.7 Some Special P-Models in Chance-Constrained Programming, A. CHARNES, *Northwestern University, Evanston, Illinois and* M. J. L. KIRBY, *Research Analysis Corporation, McClean, Virginia.*

FRIDAY NOON, NOVEMBER 5 CONTINENTAL ROOM

12:00–1:15

Luncheon

Speaker: DR. GEORGE E. KIMBALL, *Arthur D. Little, Inc.*
Subject:
"Don't Fence Me In or The Boundaries Between O.R. and Other Subjects, Such as Systems Analysis, Cybernetics, Management Sciences, Etc."

FRIDAY AFTERNOON, NOVEMBER 5 EMERALD ROOM

Session D-1: 1:30–5:00

O.R.: An Effective Aid in Municipal Planning

Chairman: MR. HAYWARD LANE
Profit Development and Control Corporation, 3407 Montrose,
Houston, Texas.

D-1.1 **The Hopefulness Syndrome and Long-Range Planning,** BERNARD N. SAMERS, *Dunlap and Associates, Inc., 123 High Ridge Road, Stamford, Connecticut 06905.*

D-1.2***The Metropolitan Data Center; A Key Tool for Local Planning,** ROBERT L. WEGNER, SR., *Tulsa Metropolitan Area Planning Commission, 600 Kennedy Building, Tulsa, Oklahoma 74103.*

D-1.3***Application of Heuristic Gaming to Urban Problems,** RICHARD D. DUKE and BARTON R. BURKHALTER, *Institute for Community Development, Michigan State University, Lansing, Michigan.*

D-1.4 **Transit Service Optimization,** ROBERT S. SCOTT, *New York State Office of Transportation, P.O. Box 7023, Albany, New York and* CHARLES R. GUINN, *Bureau of Planning, New York State Department of Public Works, State Campus, Albany, New York.*

D-1.5 **Planning for Optimal Water Resource Development,** CHARLES S. BEIGHTLER *and* WILBUR L. MEIER, *College of Engineering, University of Texas, Austin, Texas 78712.*

D-1.6***Municipal Planning for Wartime Emergencies,** WALTER D. WOOD *and* ROBERT J. FLANAGAN, *The Dikewood Corporation, Albuquerque, New Mexico.*

D-1.7***A Cost-Effectiveness Computer Procedure for Optimum Allocation of Fallout Shelter System Funds Under Uniform or Variable Risk Assumptions,** EDGAR A. PARSONS *and* FLOYD M. GUESS, *Research Triangle Institute, P.O. Box 490, Durham, North Carolina.*

FRIDAY AFTERNOON, NOVEMBER 5 GRECIAN ROOM

Session D-2: 1:30–5:00

PERT-CPM: Recent Applications and Techniques

Chairman: DR. A. W. WORTHAM
Industrial Engineering Department, Texas A&M University,
College Station, Texas.

D-2.1 **CPM-PERT Scheduling for a Large Industrial Project,** C. K. JHA, *Lester B. Knight & Associates, Inc., 549 W. Randolph, Chicago, Illinois 60606.*

D-2.2 **Evaluation of R&D Projects Using Network Planning Techniques,** COL. I. JACOB, *Military P.O. Box 2154, Tel-Aviv, Israel.*

D-2.3 **Application of PERT to Financial Month-End Closing-Procedures,** CARL A. PALLO, *Anaconda Aluminum Company, P.O. Box 1654, Louisville, Kentucky 40201.*

D-2.4 **Using PERT-CPM as an Aid in Planning and Managing New and Complex Medical and Surgical Procedures,** JOHN M. LONG, WILLIAM J. FLANIGAN *and* MASUKI HARA, *University of Arkansas Medical Center, 4301 West Markham Street, Little Rock, Arkansas.*

D-2.5 **The Voluntary Application of PERT in a Commercial Research and Engineering Development Program,** M. POLOMOSCANIK, *Current Planning Department, Xerox Research and Engineering Center, Webster, New York.*

D-2.6 **Critical Path Scheduling: Tableau Method,** JAMES L. RIGGS *and* MICHAEL S. INOUE, *Department of Mechanical and Industrial Engineering, Oregon State University, Corvallis, Oregon 07331.*

D-2.7 **Project Cost Curves, Some Equivalent Graph Theorems,** V. K. HANDA, *Department of Civil Engineering, University of Waterloo, Waterloo Ontario, Canada.*

D-2.8 **Optimal Resource Allocation in Activity Networks,** P. M. GHARE, *Industrial Engineering Department, Texas Technological College, Lubbock, Texas.*

D-2.9***PERT: Problems to Resolve,** H. O. HARTLEY *and* A. W. WORTHAM, *Institute of Statistics, Texas A&M University, College Station, Texas.*

FRIDAY AFTERNOON, NOVEMBER 5 CASTILLIAN ROOM

Session D-3: 1:30–5:00

Special Applications and Techniques in O.R.

Chairman: MR. J. T. DWYER
Ernst & Ernst, Gulf Building, Houston, Texas.

D-3.1 **A Cost Sensitivity Analysis of Major Design Characteristics of GHOST and SCOMO Meteorological Systems,** ROBERT M. CARLISLE, *System Analysis Dept., Bendix Systems Division, Ann Arbor, Michigan.*

D-3.2 **Rating of Race Horses' Performance,** ROBERT A. PORTER, *Spindletop Research, Inc., Lexington, Kentucky.*

D-3.3 **Generalized Models for Allocating Demographically-Dependent Manpower Resources,** JACOB A. WILLIAMS *and* WILLIAM L. MOOG, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland 21235.*

D-3.4 **An Application of Inventory Methods to Evaluate Staffing Levels of Professional Personnel,** SYLVAN HACK *and* FRANCIS ICHNIOWSKI, *Social Security Administration, Dept. of Health, Education, and Welfare, Baltimore, Maryland 21235.*

D-3.5 **Some OR Uses of Binomial and Poisson Probability Distributions,** JOHN E. WALSH, *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California 90406.*

D-3.6 **Mean Value Estimation from Digital Computer Simulation,** A. V. GAFARIAN *and* C. J. ANCKER, JR., *System Development Corporation, Santa Monica, California.*

D-3.7 **An Investigation of Decision Systems for a Complex Management Game,** ROBERT B. DESJARDINS, *School of Business Administration, University of North Carolina, Chapel Hill, North Carolina.*

D-3.8 **Decision Networks: A Methodology for Evaluating the Future Payoffs from Technology Development Programs,** CHARLES W. FOREMAN *and* FRANK P. MERTES, JR., *Analytic Services, Inc., 5613 Leesburg Pike, Falls Church, Virginia 22041.*

D-3.9 **Optimal Information Flow in an Organization,** SANT R. ARORA, *Mechanical Engineering Department, University of Minnesota, Minneapolis Minnesota.*

D-3.10 **Simulation: A Decision Device for Resource Allocation,** A. P. FEDDERSEN *and* W. D. O'GRADY, *Autonetics, 3370 Miraloma, Anaheim, California.*

FRIDAY AFTERNOON, NOVEMBER 5 CONTINENTAL ROOM

Session D-4: 1:30–5:00

Algorithmic Extensions to Operations Research Theory

Chairman: DR. ARNOLD E. SAFFER
Humble Oil and Refining Company, Humble Building, Houston, Texas.

D-4.1 **The Zero One Problem,** HARVEY GLASS, *Dept. of Applied Mathematics and Computer Sciences, School of Engineering, Washington University, St. Louis, Missouri 63130.*

D-4.2 **An Algorithm for Integer Linear Programming,** ROBERT A. COOK *and* LEON COOPER, *Dept. of Applied Mathematics and Computer Sciences, Washington University, St. Louis, Missouri 63130.*

D-4.3 **Practical Methods of Integer Linear Programming,** C. A. TRAUTH, JR. *and* R. E. WOOLSEY, *Computer Mathematics Division, Sandia Laboratory, Albuquerque, New Mexico.*

D-4.4 **Operational Experience with a Mixed Integer Algorithm,** NORMAN J. DRIEBEEK, *Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts.*

D-4.5 **Solution of Problems by the Method of Steepest Descent,** K. E. GEIB, D. S. HAGUE *and* E. E. MASON, *McDonnell Automation Center, P.O. Box 516, St. Louis, Missouri 63166.*

D-4.6 **On Solving Calculus of Variations Problems with Constraints Using Gradient Techniques,** P. L. ODELL *and* JAMES MEEK, *University of Texas, Austin, Texas.*

D-4.7 **Electric Utility Application of Linear Programming with Variable Cost Algorithm,** JOSEPH K. FURST, *Operations Analysis Section, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pennsylvania.*

D-4.8 **An Application of Linear Programming to the Optimization of Materiel Airlifts,** S. P. GINDER, *Dunlap and Associates, Inc., 1050 31st Street, N.W., Washington, D.C. 20007.*

D-4.9 **The Process Concept as a Basis for Simulation Modelling,** PATRICE BLUNDEN *and* HOWARD S. KRASNOW, *IBM Advanced Systems Development Division, 2651 Strang Blvd., Yorktown Heights, New York 10598.*

ABSTRACTS OF PAPERS

A-1.1 Analytical Methods in Banking, KALMAN J. COHEN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

Some major developments have occurred in recent years which make possible significant improvements in the practice of bank management. Bankers have traditionally based their decisions on memory, judgment, and intuition. A small number of progressive banks are discovering that new managerial techniques have been developed which enable them to improve their performance. These techniques arise from such diverse academic disciplines as economics, mathematics, statistics, and the behavioral sciences. It was not until electronic computers became commonplace in banks, however, that the applications of these techniques became operationally feasible. While computers are widely used in banks for performing clerical operations, their usefulness to bank management in the problem solving process is only dimly understood. Actual applications of analytical methods in banking are now being published in both academic literature and professional banking journals. Perhaps of even greater future significance to bank management, a growing number of academic articles are appearing which develop concepts and techniques of potential applicability to banking problems. This paper will review the most important work which has been done (both published and unpublished) in developing and applying analytical methods in banking. This review will be divided into five broad areas of banking problems: asset management, the lending and credit function, the trust department, the bond department, and general banking problems.

A-1.2 Adventures in ORBIT (Operations Research in Banking, Investments and Trusts), ROBERT L KRAMER, *Bankers Trust Company, 16 Wall Street, New York, New York.*

The banking industry has been among the most recent to apply the tools of Operations Research. Several reasons for the industry's comparative slowness to adopt the O.R. approach are discussed in this paper. It is noted that some of these factors still exist, to plague the conduct and implementation of O.R. projects. Two specific examples are used to illustrate some of these pitfalls. Coupon schedules for municipal bond issues have traditionally been set by "hunch," or educated guess. The optimal schedules can now be determined by a computer. The paper discusses some of the difficulties encountered, due to the unfamiliarity of bond department personnel with the ways of research. The second example demonstrates some problems that can arise from the opposite direction. The project discussed in this context involved the optimal allocation of "lock boxes" for large corporate customers. The mathematical analysis, involving heuristic programming and simulation, was reasonably straightforward. However, it was found that the subtle nuances of the customer "relationship" had to be considered before the project could be successfully completed.

A-1.3 Application of Linear Programming to the Choice of a Capital Structure, William Beranek, *Professor of Commerce, University of Wisconsin, Madison, Wisconsin.*

The procedure assumes that the function relating incremental returns to the amount invested can be approximated by a piece-wise linear function. It also assumes that the firm is confronted with a variety of opportunities of obtaining funds through different bond contracts, preferred stock contracts, and through common stock. Each of these offerings is conditional on the firm being able to satisfy a host of restrictions such as, for example, an upper limit on its debt ratio or its preferred stock ratio or a minimum value for the number of times its fixed charges will be earned. Any one of these restrictions, which may be expressed as a linear constraint, becomes operative if, and only if, the corresponding security is issued. The objective function may be in terms of either total profits or the value of the common stock. In the latter case, some information is required which relates the value of the firm's common stock to the firm's financial characteristics. The optimal solution is then found by multistage linear programming.

A-1.4 On the Simulation of Investment Behavior, Geoffrey P. E. Clarkson, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Research on the simulation of human decision behavior has created the possibility of subjecting actual investment decision procedures to empirical investigation. This paper is concerned with the application of experimental analysis to two decision models which represent, respectively, the portfolio selection process of an institutional investor and a price-setting mechanism on the Over-the-Counter security market. The former model is capable of replicating the portfolio selections of a specific investor. The latter represents the interaction that takes place between broker and trader on the Over-the-Counter market which results, over time, in a sequence of prices for a given security. The existence of such models provides a basis for a critical examination of the decision procedures themselves. Portfolio selection processes can be tested for their ability to perform well under varying market conditions. Price-setting mechanisms can be inspected for the statistical characteristics of the time series they produce. In brief, the ability to construct testable models of decision behavior permits some normative issues to be resolved by the application of procedures that are common to all branches of applied science.

A-1.5 Loan Operation Profit Maximization Through O.R., Frederick B. Cornish, *Ernst and Ernst, Fidelity-Philadelphia Trust Bldg., Philadelphia, Pennsylvania 19109.*

The loan function in banks and financial institutions is approached as a problem in resource allocation. Sub-models to answer the following questions were necessary to develop the criteria for the allocation model: Can the relationship between loan quality, yield and liquidation losses be established? What standards should be established for quality and yield? Can credit-screening factors be established for minimizing the delinquency rate? Can changes in real estate values be forecasted and potential effects on loan yields determined? Can future monies available and the flow of this cash be meaningfully predicted? Each sub-model in itself provides guidelines for modifying and improving loan policy so that direct benefit is derived as each sub-model is completed.

A-1.6 An Application of Heuristic Problem Solving to Accounts Receivable Management, FERDINAND K. LEVY, *Department of Economics and Business Administration, Rice University, Houston, Texas.*

The paper describes a very apparent application of heuristic problem solving to accounts receivable management, namely in the location of lock-boxes. Lock-boxes are post office boxes selected in a company's distribution area in order to minimize the time necessary for the company to collect and have available the funds remitted by its customers in payment of their obligations. The paper starts with a mathematical formulation of the problem which can be solved by integer programming methods. Of particular interest in the statement of the problem is how a set of locations is measured. Next the difficulties with the formulation are pointed out and a heuristic program to reach a satisfactory solution is described. The program is written in FORTRAN IV and is currently being tested.

A-1.7 Scheduling Branch Pickups and Deliveries, DONALD B. BROUT, *Arthur Young and Company, 277 Park Avenue, New York, New York 10017.*

Variations of a truck dispatching technique have been applied to determining the appropriate number of trucks and developing good truck schedules for a large bank with over 80 branches. Trips having different purposes were scheduled using different criteria. Both one-way trips and round trips were considered. Larger branches were given preference during certain times of the day by weighting trip times in proportion to the size of the branches visited. Solutions were generated using a small computer, and future revisions to meet changing conditions have been facilitated. The technique was suggested by the work of Dantzig and Ramser (Management Science Vol. 6, No. 1, pp 80-91) and Clarke and Wright (ORSA Vol. 12, No. 4, pp 568–581). Generalizations were developed to handle the weighting of stops for service preference, the one-way trip problem, and restrictions on the duration of the longest trip. (In another application in a different industry, the use of secondary terminals remote from the main terminal has also been included.) The bank was able to reduce the number of trucks owned by 17% and the total truck operating hours by 23%. The number of stops was reduced by one-third.

A-2.1 Plant Investment Problem, NEAL CLEARY, *Phillips Petroleum Co., Bartlesville, Oklahoma.*

Recent developments in nonlinear programming have enabled the operations research analyst to formulate and solve more complicated and realistic models of manufacturing facilities. This paper describes the formulation of and results obtained from a nonlinear model of a hypothetical petroleum refinery The relaxation of the linearity restrictions allows the components of the refinery to be more realistically represented and removes many of the sources of error in the blending of the products produced by the refinery. This study was motivated by the desire to build a computer program which could be used to evaluate proposed refinery plant investments. The program will, subject to a specified set of product demands and prices, determine which of several crude oils to process at what level and will select the optimum type and size of units to comprise the refinery. The processing units considered are; crude unit, platformer, cat cracker, alkylation unit and cat poly unit.

A-2.2 On Implementing Operations Research in a Decentralized Company, WILLIAM R. DAVISON, *Standard Oil Company (Indiana), 910 South Michigan Avenue, Chicago, Illinois.*

A decentralized organization is one composed of several autonomous self-contained operating companies functioning within financial and policy controls laid down by the parent company. This mode of organization possesses several inherent characteristics which tend to favor the effective implementation of operations research at all levels of the organization. The fact of decentralization can stimulate the development of strong technical capabilities as a result of efforts by each subsidiary to be self-sufficient and to produce outstanding performance records. Where these forces are operating, managers tend to be unusually receptive to methods and techniques which may improve performance. In such an environment, the professionally qualified O/R practitioner can function effectively as a promoter of, and consultant in, O/R techniques, using operating department personnel themselves to develop specific applications. This approach spreads knowledge about proved O/R techniques throughout the operating departments, and tends to produce a group of managers who possess more than a superficial understanding of the objectives and methods of O/R. On the other hand, applications may tend to be limited in scope unless adequate coordination of effort is provided, particularly with reference to problems which cross organizational boundaries. An account of primary areas of O/R work to date as well as directions of future work, and a brief discussion of organizational aspects is presented.

A-2.3 The Profit Contribution of Linear Programming to the Management of Forest Industries, C. G. EDGE, *Chemcell (1963) Limited, 1155 Dorchester Boulevard West, Montreal 2, Quebec, Canada.*

The paper will discuss the management of forest industries, including the nature of the business, the complexity of the problem, traditional approaches to decision making, the time horizon of forestry decisions, and problems of measurement. The applicability of linear programming for allocating woodland resources and the nature of constraints will be reviewed with indications of similarities with the oil industry. Illustrations will be provided from a case study of the introduction of linear programming into a British Columbian pulp and lumber company covering the organization of the project, costing problems, and the results obtained. Discussion will follow on the management attitude to linear programming, the degree of acceptance, problems of implementation and an assessment of the value to the company as a planning tool for the enhancement of profits.

A-2.4 An Optimal Plant Location Study, W. G. WELTER, *34 Hillcrest, Ponca City, Oklahoma.*

The several factors influencing the potential location and size of an industrial plant and inventory in the general case are discussed, along with the difficulties encountered in formulating an omnipurpose plant sizing computer program. The analysis of these factors in the context of a real problem is then discussed, the method of solution of this problem is justified, and a diary of the case is presented. The problem solved is multi-product and time dependent.

A-2.5 Optimal Digital Control of a Chemical Reactor, George L. Nemhauser, *The Johns Hopkins University, Baltimore, Maryland and* Michael E. Thomas, *University of Florida, Gainesville, Florida.*

An application of optimal control theory to on-line digital control of a chemical process is considered. The cost of operating a process includes two terms; the first is associated with deviations from the desired operating point, the second term is included to represent costs of exercising control. The optimal feedback control law is developed for a linearized version of a tubular reactor model affected by arbitrary changes in the feedrate. The results of this scheme are compared with conventional control techniques and the optimal linear control law is shown to be substantially better. A time-varying linear approximation to the reactor model is proposed when large deviations from the set point are encountered. Each approximation scheme is compared to the numerical solution of the non-linear reactor model. It is shown that for small deviations from the operating point it is satisfactory to use the ordinary linear approximation. However, for large upsets, the time-varying linear approximation is needed to obtain adequate results.

A-2.6 Towards an Automated 'Total' Information System, S. Ray Adkins, *The Mead Corporation, Dayton, Ohio, and* John F. Pierce, *IBM Systems Research and Development Center, Cambridge, Massachusetts.*

The conceptual framework underlying an automated 'total' information system currently under development at The Mead Corporation is presented. This framework is elaborated in the context of the White Papers Division, a multi-plant division of the corporation supplying a wide variety of papers. The implementation schedules, objectives, and difficulties involved in such a system are discussed with particular reference to the development and initial installation of the production-distribution planning and scheduling models.

A-3.1 BRAT (Acronym for BRanching Analysis Technology): An Approach to System Definition, Synthesis, and Effectiveness Assessment, R. R. Boyce *and* E. V. Bruchez, *Martin Company, Orlando, Florida.*

BRAT, an information flow network, was first introduced to define a naval combatant ship to provide measures of effectiveness in terms of accepted ship's characteristics. This network is easy to construct and is adaptable to any functional system—an automobile, an OR team, a ship, or a factory. BRAT is based on the precept that mutually exclusive diagrams which show only functional operations or placement of parts can be combined to form networks which define and synthesize systems and can be used to assess system effectiveness. Also, if a measure of system effectiveness is given, the flow of information through the network provides a guideline for estimating relative worths of components or subsystems. By this process, an effective and relatively invulnerable system may be defined and synthesized.

Conceptually, this synthesis leads to the design and development of systems which are characterized by adequate redundancy, planned sharing, and elimination of unnecessary parts. BRAT provides ample opportunity to incorporate the operations research principle of combining subjective judgment with objective analysis. The purpose of the paper is to explain how BRAT is constructed and how it can be used.

A-3.2 Weapon Allocation for Fallout Attacks, FLOYD I. JOHN *and* JOHN W. ULRICH, *Stanford Research Institute, Menlo Park, California.*

Fallout attacks are of particular concern to the Office of Civil Defense because the problem of casualties resulting from a fallout attack is an important one and the Office of Civil Defense can do something to reduce the number of casualties in the event of an attack. To assess the magnitude of the threat, it is necessary to estimate, realistically, the maximum number of casualties that might result from a fallout attack. To do this, the weapons must be allocated in an optimum manner over the target area. The optimization problem is complicated by the interaction of the effects of the weapons and by the fact that the location, as well as the number, of weapons is important. The problem is complicated further by the form of the objective function. If the empirical data are left in tabular form, then the computer representation of the objective function requires more high speed core than is available on many computers. If the data are reduced to functional form, the complexity of the function results in high computation times. In the face of such difficulties, some major simplifications are often made which overly color the result. In this paper we present methods which, in some cases, avoid these difficulties. The methods fall into two categories, the representation of the data in a modified tabular form and the decomposition of the objective function into a sum of simpler functions which may be maximized sequentially. Several examples will be given from weapon allocation studies made at SRI.

A-3.3 A Damage-Limiting Shelter-Allocation Strategy, GRACE J. KELLEHER, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia 22202.*

A damage-limiting strategy for allocating blast and fallout shelters for protection against nuclear attack is described. The proposed strategy is to provide a given city or metropolitan area the least-cost shelter posture that will limit fatalities from a given weapon to a stipulated level regardless of where the weapon is delivered in the area. The strategy is executed with a unique allocation model that takes all possible ground zeros into consideration and applies least-cost decision rules in selecting the specific shelter strengths to be allocated to the population of each one-square-kilometer element of the target area matrix. As will be demonstrated, postures developed by this strategy against a single weapon of a given yield will, at the same cost, also prove highly (if not optimally) effective against weapons of different yields. This shelter-allocation strategy was tested by designing and costing alternative shelter postures for protection of the *Houston* population. The results are reported.

A-3.4 The Effect of Monitoring System Performance on Force Effectiveness,

Jay W. Miller, *The Boeing Company, Aero-Space Division, Seattle, Washington.*

A detailed examination of shoot-look-shoot . . . etc. that takes into account the characteristics of some proposed target kill assessment (TKA) systems is the subject of this paper. In particular, the effect of the following variables on the possible weapons savings is shown: (1) desired percent of target complex to be destroyed, (2) single shot probability of destroying a target, P_k, (3) number of separate salvos to be employed, (4) the portion monitored of the sequence of actions involved in an individual shot, and (5) the probability of an incorrect report from the monitoring system. The analysis calculates the force size required to achieve an expected number of targets killed as a function of the five parameters listed above. Results of some design exercises are utilized to establish realistic characteristics for the TKA systems. An important feature of the study is a determination of the optimum number of weapons to employ in each salvo. An approximate analysis that omits fractional weapon assignments on a target and that applies for a perfect TKA system can be seriously in error both as to optimum force expenditure schedule and force savings achieved. This study allows for TKA imperfections and sticks to integral numbers of weapons on each target in finding the optimum expenditure of weapons per salvo. Numerical results show that TKA system imperfections can have a serious effect on possible force savings. For instance, if an expected kill of 90% of the target complex is desired, the weapons used have a single shot kill probability of 0.60 (or failure probability = 0.40), an unlimited number of salvos are employed and the TKA system is perfect, only 0.57 times as many weapons are required as when TKA is not used. That is, there is a saving of 43% of the force. Now if one is restricted to only two salvos, the TKA system is able to monitor only 80% of the failure probability and only 90% of the TKA reports are correct, the force saving is reduced from 43% to 21%.

A-3.5 An Analytical Solution for Periodic Maintenance of a System,

James F. Daughtry, III, *The Bunker-Ramo Corporation, 8433 Fallbrook Avenue, Canoga Park, California 91304.*

A typical problem that might arise in evaluating the performance of a system can be stated in the following manner. Given a scheduled sequence of operations of preventive maintenance and a set of parameters associated with tests and repairs, how often should an operational sequence be repeated such that a given measure of effectiveness attains its optimum value? This is the problem to which the analysis is addressed. It is assumed that system failure is describable in terms of a stochastic process. In formulating an analytical expression for the probability of a system being operational, the probability of failure function is proven to be harmonic, i.e., the system failure function initially oscillates randomly and passes through a transient state and after a large number of cycles stabilizes exhibiting a periodic property. The equation for the probability of the system being operational is a polynomial function with constant coefficients which can be readily solved by standard methods. The usefulness of the model is indicated by the ease with which the model can be extended to the analysis of multiple systems and the inclusion of cost considerations in maximizing the capability of a system. A typical application of the model is given by analyzing the probability of a missile system being in an operational ready state.

A-3.6 Kill Probability Model for Multiple Dependent Shots, G. L. Gallagher, *Autonetics, 3370 Miraloma Avenue, Anaheim, California 92803.*

The common method of computing probability of kill, P_K, for multiple shots on point targets has been through use of the formula: $P_K(N) = 1 - [1 - P_K(1)]^N$. However, the underlying assumption behind this formula is that the N shots are totally independent. In reality, rather than the missile accuracy (target miss distance) being entirely random, a portion of the accuracy variance is common (fixed but unknown) to all N shots on the given target. This common "bias" will cause the shots to cluster about this "bias" point rather than the target itself. A new analytical approach to this problem resulting in a simple graphical evaluation of a rather complicated integral involving integration of the product of two correlated multivariate normal density functions over variable limits is developed.

A-3.7 Modeling the Civilian and Military Manpower Environment in the 65–74 Era, G. Bernstein *and* H. Safeer, *Research Analysis Corporation, McLean, Virginia.*

Previous attempts in analysing the impact of alternative civilian and manpower policies heretofore have been limited to a manual exercise. The serious limitations of this system were: (1) Only a very limited set of alternative policies could be assessed, and (2) The interface between civilian and military policies could not be fully appreciated. As part of an overall study of military manpower policy by DOD (by Presidential request in April, 1964) RAC developed a computerized military-civilian manpower projection model. This model projects the impact of alternative military and civilian manpower management policies considering a wide range of alternatives including: (1) continuation of the draft in its present form, (2) modifying the present structure of the draft, (3) elimination of the present draft, (4) changes in force size, (5) changes in force requirements, (6) changes in military pay, and (7) changes in military obligation, training patterns and other institutional practices. The principle outputs of the model include, but are not limited to: (1) flows of manpower from the civilian and military pools, (2) an annual projection of the age, education, family and military liability status of the male population, (3) a summary of the strength, gains and losses of each of the active duty military components, and (4) the costs associated with procuring, training, maintaining and separating military manpower. This model is now operational and has been used to generate projections for the 1964-65 DOD Military Manpower Policy Study to be sent to the President this May.

A-3.8 The Cost/Effectiveness of Reenlistment Incentives in the Navy—a Simulation Study, Anton S. Morton, *Institute of Naval Studies, Center for Naval Analyses, 545 Technology Square, Cambridge 39, Massachusetts, and* Franklin M. Fisher, *Department of Economics, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.*

Since 1947, the Navy has suffered shortages of experienced electronics maintenance personnel, because of too low a first term reenlistment rate. A non-linear dynamic model was developed to investigate the trade-off between costs and effectiveness of additional career incentives. Costs per longevity year were determined for the Navy with present incentives and reenlistment rates. Survey responses were used to estimate reenlistment rates for 22 additional incentives, and added costs were determined. Operational usefulness of men was chosen as the measure of effectiveness. Relative demand factors for four usefulness classes were derived from weighted average estimates made by experienced supervisors. A Cobb-Douglas utility function expressed operational effectiveness, both actual and required, as a multiplicative function of the number of men in each usefulness class. Effectiveness requirements which could be achieved by a Navy of specified characteristics were set up for a 30-year time frame. For each incentive situation, the model, using an iterative convergence solution, derived the optimal pattern of annual recruit inputs—the pattern that would at least achieve effectiveness goals, at minimal present discounted cost. The sensitivity of results to assumptions was tested. The *optima* were compared, indicating which incentives would at least achieve the effectiveness requirements at minimum cost.

A-3.9 Nuclear Cost Assessment Technique (NUCAT), CARLTON COMBS JR, DAVID C. BROWN *and* RICHARD D. CUTHBERT, *Combat Operations Research Group, P. O. Box 116, Fort Belvoir, Virginia.*

This paper describes a computer model developed by the Combat Operations Research Group (CORG) to support a nuclear weapon cost-effectiveness study for Headquarters, US Army Combat Developments Command. The model was designed to assist operations analysts in the examination of a set of nuclear delivery systems on a cost-effectiveness basis, by simulating the firing of each of these weapons against a given set of targets. Since the calculations performed by the model are basic to the concept of cost-effectiveness, the computer program is designed to facilitate modification and adaption for use in other studies and analyses.

A-3.10 Vulnerability Influence on Cost Effectiveness of Tactical Airborne Vehicles, R. W. ALLEN, *Douglas Aircraft Company, Inc., Santa Monica, California.*

The use of airborne tactical vehicles in tactical air assault operations has lately received considerable attention because of its potential advantages in increasing the mobility of battle field missions. One of the prominent types of vehicles employed is the helicopter. The helicopter, with its low altitude, high maneuverability, and the capability of transporting troops and equipment in the battlefield environment, produces a rather useful military vehicle. On the other hand, its relatively slow speed performance characteristics and high vulnerable structure makes it rather vulnerable to small arms ground fire. Recent events in Vietnam, concerning helicopters that were attacked by ground fire and shot down, have highlighted the helicopter's vulnerability. The question that frequently arises is whether protection of the vital parts of the vehicle and/or increased fire power will improve the mission effectiveness with justifiable costs. This study examines the effects of vehicle protection and/or increased fire power on the system cost effectiveness when under a tactical assault mission and subject to small arms ground fire.

A simplified approach is used in order to quickly highlight the important elements and examples which are presented in parametric form to show the interaction of the important factors.

B-1.1 Corporate Model for Steel Production, W. O. Blattner, *United States Steel Corporation, Pittsburgh, Pennsylvania.*

United States Steel Corporation produces raw materials at multiple mining locations and ships them to multiple steel producing plants. An LP model has been developed and is used as the basis for establishing optimum raw material allocations and operating plans. The heart of the model is a set of technological relationships describing the blast furnace process for conversion of raw material to iron, which have been evolved over a number of years. Experience gained in the successful development and implementation of the model and the problems involved in maintaining it as an up-to-date management control tool will be discussed.

B-1.2 A Refinery and Distribution Planning System, Jack M. Gillette, *Bonner and Moore Associates, Inc., 500 Jefferson Building, Suite 1124, Houston, Texas.*

This paper describes a system to be used for petroleum refining and distribution planning using mathematical programming. A brief description of the final system is given, but the paper concentrates on the problems of developing proper cost elements from accounting data. Some pitfalls and solutions are described. The system will be used for studies which fall into two basic categories: (1) develop operating plans to satisfy sales demands considering alternative methods of manufacture and shipment, but using existing facilities, and (2) evaluate locations and type of facilities and develop capital investment plans to satisfy sales demands more economically. These two types of studies can require different objective function values. The handling of cost elements and considerations of objective function values are discussed in detail.

B-1.3 PDP—A Broad Spectrum Planning and Control System, Charles Lewis, *General Mills, Minneapolis, Minnesota.*

The Production/Distribution Planning (PDP) system discussed in this paper is the successor system to one developed six years ago at General Mills. During that time the system which basically answered the question "How do we produce and distribute at minimum cost?", has been used for facilities planning and current planning. Since the predecessor system was of limited scope more effort was being used in fitting the model to the problems than in answering management's questions. A new system has been developed to meet the expanding requirements inherent in "How do we produce and distribute for maximum profit?". The model for this new system is quite general in that it breaks down any flow process, without feedback, into the basic stages of Acquisition, Production, Inventory and Marketing, with Transportation providing the links between successive stages. In concept PDP may be thought of as a multi-product, multi-stage, multi-time period network flow problem with capacities possible on both nodes and arcs. The capability to handle conditional freight rates, as in rail transit movements, has also been built into the system. The system will handle production stages of the translation type—one product in, same product out; of the synthesis type—many ingredients in, one product out; and of the analysis type—one product in and many products and by-products out. The size of problems which will be considered with this system will be in the millions of variables and constraints category when stated as a linear program. Even with the low coefficient matrix densities encountered in these problems the input task is of major proportions. To efficiently handle this problem a compiler type input has been developed in exception and restriction format to be inputed in management's own language. The compiler then reduces this input and translates it into information the system needs for a solution.

B-1.4 Non-Linear Distribution Problems, B. R. Buzby, *Management Services Department, Union Carbide Corporation, 270 Park Avenue, New York, New York 10017.*

Distribution models, containing facilities having non-linear costs, have long resisted computational solution. The optimum program must typically balance the increased capital costs incurred in installing depots, pipelines, docks, etc., with the decreased transportation costs. Benders published in 1961 an algorithm for solving this and more general mixed integer problems. We wish to describe our experience over the past year with one computer program implementation of this algorithm. This will be done by describing several practical distribution, network problems that have been solved. In addition, actual computer experience on a large number of randomly constructed distribution problems will be summarized.

B-1.5 A Practical Simulation of Corporate Financial Operations or CORBUS, Frederick B. Cornish, *Ernst and Ernst, Fidelity-Philadelphia Trust Bldg., Philadelphia, Pennsylvania 19109.*

The model describes in mathematical terms the operations of a going manufacturing concern having three interrelated product lines. The model is deterministic rather than statistical. The model simulates the response of the company to the market-place during a time period and by a feedback loop adjusts following time periods accordingly. The model ties together: an operating plan for each time period in which financial component values are all computed on the basis of operating results expected, the effect of engineering and research expenditures as they affect revenue thru product utility and improved production methods, the effect asset utilization has on production costs, the company's response to the market-place in terms of: its sales price to its competitor's price, its product utility, its marketing effort, etc. Also taken into account is the lag between engineering expenditures and their effect in the market-place, marketing expenditures and their effect, and advertising expenditures and their effect. The results are measured in terms of: return on revenue, return on assets, asset turnover, unused borrowing or leverage capacity. It is a live model, programmed and running Algol '60.

B-1.6 International Market Distribution Simulation Model, C. H. Chyung, *International Minerals and Chemical, Skokie, Illinois 60078.*

The paper stresses various aspects of building a simulation model designed for the analysis of competitive conditions in the overseas markets involving raw material products. The problem is formulated as a series of linear equations which express both the physical bounds of the situation, activities and the associated costs of the alternatives. The model represents a production capacity of the entire world (tons per annum) and covers up to 130 major marketing areas. Not only would the economic benefits from the coordination and optimization of operations on this scale have been large, but the whole approach to corporate planning and strategies could radically change within the company. The emphasis of the paper is on model building and the analyses of the results as a decision-making tool, rather than a discussion of the computational code or problems.

B-1.7 Drawing Valid Conclusions from Corporate Simulations, MALCOLM H. GOTTERER, *The Pennsylvania State University, University Park, Pennsylvania 16802.*

This paper deals with the statistical problems of analyzing the output of corporate simulations. The simulator is perceived as an experimental device on which various experiments may be performed. Due to the large number of parameters that are present in any meaningful simulation model of the firm, it is necessary to plan these experiments so that the response surfaces may be analyzed and appropriate conclusions drawn. Various methods for drawing valid conclusions based on carefully designed experiments using simulators will be presented and each discussed.

B-2.1 Peak-Period Analysis and Control of a Freeway System, JOSEPH A. WATTLEWORTH, *Texas Transportation Institute, Texas A&M University, College Station, Texas.*

Several methods of operating a system of freeway ramp controls during morning and afternoon rush or peak periods are currently under consideration in traffic engineering circles. This paper presents some ideas on an optimization approach to this control problem. The variable to be optimized (in this case maximized) is the total output rate of the critical portion of the freeway system, since this has been shown to be essentially equivalent to minimizing the total travel time occurring to all vehicles which use the freeway during the peak period. In the control system proposed, each freeway entrance ramp (in the direction of peak flow) is metered at a rate which maintains the total merging flow rate at or below a rate set by a central computer. The central computer determines the optimum merging flow rates by solving an appropriate linear programming problem. The continuity characteristics of closed traffic systems are used: (1) to detect reduced-capacity occurrences (accidents, etc.), and (2) to determine the capacity flow rate at such locations. This information is used as input for a modified L-P model which is solved to determine optimum operation under the existing conditions.

B-2.2 The Effect of Driver Response-Time on Throughput at a Saturated Signalized-Intersection, C. J. ANCKER, JR. *and* A. V. GAFARIAN, *System Development Corporation, Santa Monica, California.*

The effect of random driver-response time on throughput at a saturated signalized-intersection is studied. The model assumes zero acceleration and deceleration time and identical terminal velocities for all vehicles. Analytic expressions are derived for the average number of vehicles that pass through the intersection during a go period. Some calculations and curves are given for the specific case of a general gamma distribution function for the response time random variable. It is shown that the usual mean value model is quite accurate for mean value purposes but that variability in response time does cause significant variance in throughput.

B-2.3 A Model for Simulating Inter-City Traffic Flows, MARTIN J. ARONOFF *and* BERNARD M. LEVIN, *Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

The National Bureau of Standards is designing a model to simulate inter-city traffic flows. This model predicts patronage of existing and proposed systems based on expected travel demand, cost, and service on competing systems. A computer program to simulate passenger traffic has been written for the IBM 7094 digital computer using the FORTRAN programming language. Traffic is generated according to a definite set of rules: the model, modular in form, decides on a routing for each traveler generated and records the simulated use of available transportation facilities. It determines how many passengers of certain types wish to travel between a given city pair at a specified time of day and determines which mode each type will take by relating his travel preference to the time and cost of each route. When all travelers have been assigned to routes for each origin-destination pair, the time of day is advanced and the procedure is repeated. Summary data are collected and printed periodically throughout the run. It is anticipated that the model will provide information useful in making decisions regarding the future transportation system between Boston and Washington.

B-2.4 Individual Preferences for Various Means of Transportation, FRANK BENSON *and* MILES MARTIN, *Department of Statistics and Operations Research, University of Pennsylvania, Philadelphia 4, Pennsylvania.*

The relative values placed on the cost, elapsed travel time, comfort, and convenience of available alternative urban transportation systems was measured for 400 users in the metropolitan Philadelphia area using structured personal interviews. Increments in these factors sufficient to cause a shift in modal split, as reported by each individual, was determined as a function of base quantities. Means of the distributions of these increment functions were calculated and used as a standard against which each individual was compared. Degree of sensitivity to each parameter was then defined as deviance from the standard. Individuals aggregated on the basis of primary sensitivity behave in accordance with an elementary decision model which says that cost sensitive people choose the cheapest alternative, time sensitive people choose the fastest mode, etc. The behavior of 100 additional urbanites was predicted using this model and predictions compared with those of a socio-economic regression model. Prediction errors were approximately the same, but the utility model appears to have the advantages of: (1) beginning to explain *why* modal split occurs as it does instead of just relying on correlations, (2) leading to recommendations for modifications in existing transportation systems, and (3) providing a reasonable basis for prediction of demand when a new transportation alternative is being considered, i.e. when no historical trip behavior data is available.

B-2.5 A Domination Theorem for Optimal Locations, A. J. Goldman, *and* P. R. Meyers, *National Bureau of Standards, Washington, D.C. 20234.*

Given a geographical distribution of "customers" weighted by frequency or quantity of service required, the problem is to choose a location L for a central facility (firehouse, library, transport terminal, mail-sorting installation, food distribution point, etc.) so as to minimize the weighted sum $f(L)$ of its cost-distances from the customers. L is said to *dominate* L' if $f(L) \leq f(L')$; clearly any dominated set of locations can be deleted from the possibilities to be searched for the optimum, provided a dominator of each is retained. Assume travel is restricted to radial webs emanating from one or more "foci", and to one or more "beltways"; also suppose unit travel costs from "consolidation points" are non-increasing with the length of the trip. Under these quite general hypotheses (which can be weakened substantially, and are not entirely detailed above), the set S of locations consisting of the individual foci and all points on the beltways is shown to contain dominators of all other sites, so that the search for an optimum can be confined to S.

B-3.1 On the Role of the Digital Computer in Planning Future Space Flight Programs, Stanley Ross, *NASA, Washington, D.C.*

Against a background of continual reassessment of space program goals, and constant iteration and recalculation of the many elements within the program, the digital computer offers a means for freeing the program planner from routine, repetitious and burdensome calculations which dominate the process. The present paper undertakes a preliminary appraisal of the computer's place within the space program planning process; it seeks to develop structural elements characteristic to all space flight programs and it examines those which seem most amenable to treatment by automatic computation techniques. It discusses the role of the planner versus that of the machine (or, more correctly, the mathematical decision algorithm) in formulating "choices" which affect the program structure. Some tentative specifications and desirable operating features are advanced for the software packages indicated and, in the light of these features, several existing computer programs are examined. The paper closes with a discussion of how some new computer-related systems which appear to be forthcoming might eventually find application in conducting space program planning operations.

B-3.2 Use of Operations Research in Effective Planning of Space Missions and Space Programs, C. B. Moore *and* T. E. Peace, *Operations Research Section, General Dynamics/Fort Worth, Fort Worth, Texas.*

The magnitude and complexity of space programs preclude a direct adaptation by management of many of the conventional decision-making techniques. Total program effectiveness requires a multiplicity of effectiveness considerations during all program phases, and the subsequent integration of the key elements to which effectiveness is sensitive into a total effectiveness evaluation. In addition, a necessity for new measures and methodology of effectiveness assessment has arisen concurrently with managerial burden. This paper deals with space program planning from the selection of spacecraft systems to the delineation of long range space programs. Specific topics covered include optimization of spacecraft operational and scientific payloads, selection of mission vehicles and modes, selection of mission sequences, and the integration of the results of these sub-optimizations and interim decisions into space program plans. The role of Operations Research techniques, the use of expertise and mathematical models within the analytical framework is particularly emphasized. Effectiveness criteria discussed and used in the evaluation processes include cost, information yields, value, cost/effectiveness, timeliness, development risk, and probability of mission and program success.

B-3.3 Cost Effectiveness: Incentive Stimulant for Future Spacecraft Programs, EDWARD D. LUPO, *MSC-NASA, Houston, Texas.*

Since the early days of the Mercury program the NASA effort in manned spaceflight has been faced with one primary goal: that of pushing the "state of the art" in spacecraft design and fabrication to accomplish certain definite pre-selected objectives. With the successful completion of Project Apollo many "state of the art" advances will be sufficient to allow primary focus to shift to the problems of the economical effectiveness of alternative space programs. The paper deals with the growing tendency in the planning of future programs to reap the largest harvest possible with the technological and economic resources available. A case study of one example of the type of analysis that can be made and the possible advantages of this type of early planning is presented. Under the broad heading of cost effectiveness analysis this case serves as a primitive example of an application of the simple philosophy of cost effectiveness to the complicated problems of the planning of future space flight programs. It is proposed that through analysis of this type that incentives will be produced to provide increasing agency effectiveness via economical spaceflight concepts. Some of the technical problems of contributory solution of these analyses are discussed. The obvious inadequacy to predict the costs of entirely new programs, the difficulty of developing measures of effectiveness which are both logically adequate and quantifiable, and the problems of determining future objectives are each included.

B-3.4 Effective Design for Interplanetary Exploration Via the Availability Concept, ROY B. CARPENTER, JR., *North American Aviation, Downey, California.*

Ever since the inception of the Apollo program and perhaps even earlier, men have postulated manned planetary missions. To now, these plans have been relegated to a nebulous realm called "the foreseeable future" but the question arises why not now? This paper explores the bounds on the limiting factor, reliability/crew safety and the alternate possibilities that exist and control safe manned interplanetary exploration for the next decade. The analysis is based on the premise that the Apollo Lunar missions are feasible and a reasonable risk. The intent was to determine if Apollo level technology was adequate to support extended space missions and in particular the Manned Mars and/or Venus Flyby. The paper explores the reliability problem using the systems engineering approach to determine mission requirements in terms of functions, duty cycle and subsequent reliability; and then using the Apollo assessments, establishes the extent of the flyby mission reliability/crew safety problem. A solution is presented which brings mission success well within grasp and to a level of understanding where most can have confidence. Failures are excepted, identified and programmed into the design by application of the availability concept. The concept is applied first to the completely designed environmental control system, then the less defined life support system, and finally to the total spacecraft system. As a result, problem areas such as reliability/crew safety; maintainability; downtime constraints; spares requirements; test requirements; and operational procedures, requirements and limitations are identified and explored. The conclusions show the planetary flyby missions to be feasible within the decade and a logical evolution of Apollo.

B-3.5 An Optimization Procedure Utilizing Dynamic Programming, W. H PURCELL, JR., *Operations Research Section, General Dynamics/Fort Worth, Fort Worth, Texas.*

In this paper, the problem considered is that of finding, for a collection of systems in series—with alternate choices for each system, the minimum total cost subject to constraints on the total weight and the overall reliability. This problem is reformulated according to standard dynamic programming techniques, and for this reformulated problem, an approximate solution procedure is described. In the existence of alternates, and in the use of a product-type constraint, this problem differs somewhat from many dynamic programming problems. The requirements that these differences impose on the computerized solution procedure are discussed, and its accuracy is looked into. An example problem is presented in which the systems were such parts of a spacecraft module as life support, auxiliary power, etc.; the alternate choices were types (such as solar collector, nuclear reactor), or technological levels (such as state-of-the-art, highly advanced).

B-3.6 Application of Game Theory to Space Missions, VICTOR SELMAN, *Reliability and Operations Research, System Sciences Corporation, P. O. Box 1123, Falls Church, Virginia 22041.*

In recent years much interdisciplinary operations research activity has been innovated to assure space mission successes—both manned and unmanned categories. In particular, optimization disciplines have been brought to bear upon the selection of alternate designs to ultimately arrive at overall system effectiveness at minimum cost. The preponderant number of analyses has usually assumed some probability density function for the occurrence of various design characteristics. Unfortunately, some of the assumptions made were overly optimistic, thereby reducing the effectiveness of the overall mission. One may look upon selection of alternate designs for space missions as decision-making in the face of uncertainty. It is suggested that a pessimistic but powerful mathematical technique called theory of games may be more apropos and can help to bring the critical factors into sharp focus. Recognition of the critical factors and use of the von Neumann minimax methodology can greatly simplify the ingredients of a complex situation. It will be shown by examples how a game theoretic formulation of a space mission may enable the designer to identify irrelevant and redundant information in making logical decisions.

B-3.7 Budget Priority Analyses in Space Programs, MARK ALFANDARY-ALEXANDER, *Mathematics Branch, Operations Analysis, U.S. Atomic Energy Commission, Washington, D.C. 20545.*

In connection with space propulsion activities, an optimal budgetary allocation was determined by means of standard-lottery and mathematical programming methods. Parametric variation techniques were then used to answer the question of how budgetary reductions (or expansion/reallocation) should be made. The iterative solution obtained provided sequential statements of the project allocations based on marginal considerations.

C-1.1 Long Range Facilities Planning, CHARLES F. KNIGHT, *Lester B. Knight and Associates, Inc., 549 W. Randolph Street, Chicago, Illinois.*

A multi-plant industrial firm with national distribution to several markets is faced with the problem of having to expand production capacity to meet five-year sales forecasts. Basically. the objective is to determine what products should be manufactured and/or assembled where and in what quantity to minimise the cost of materials, manufacturing and transportation to insure maximum return on invested capital while meeting forecasted demand. A model to minimise the cost of: Assembly; Manufacturing; Materials; Interplant Transportation and Transportation to Markets was constructed and tested. The ramification of such factors as: plant locations, new plant start up costs, learning curves, new methods, new standard, variation in production and rise of work force were incorporated in the solution. The results of the study was a five-year Facilities Program calling for two new production facilities. The program is in the second year of implementation and the first new plant is under construction.

C-1.2 Profit Contribution as a Means of Evaluating a Distribution System, W. M. COHEN, *Price Waterhouse and Co., 60 Broad Street, New York, New York 10004.*

The use of the concept of profit contribution is of vital importance to management's evaluation and/or redesign of a distribution system, especially when the management of a concern is engaged in both the delivery and manufacture of products. Profit contribution is here defined to be the difference between selling price and manufacturing cost minus loading cost. For example, in an analysis of a company which had the capability of producing two dozen related products, an effective case was made for using profit contribution as the measure of effectiveness of its distribution system. The company involved in this case study had three manufacturing plants supplying products to over one hundred wholesalers representing 60% of the company's business. The remaining business being accounted for by retail and export trade. This paper presents the results and conclusions of the profit contribution analysis. It shows that the disassociation of manufacturing costs and transportation cost from dollar profit will lead to deceiving conclusions.

C-1.3 LP Solution of a Manufacturing Problem, E. E. Mason, *McDonnell Automation Center, P. O. Box 516, St. Louis, Missouri 63166.*

A large aerospace manufacturing company is using a linear programming approach to optimal budget allocations in the preparation of the design of a new mass-production assembly line facility. The preliminary design stage is underway for production facility to manufacture hundreds of small missiles per day. This abrupt departure from the normal rates of a few airplanes or large missiles per month resulted in the need for a tool to aid in budget allocations for the various portions of this new plant. Linear programming was selected as the most appropriate tool. Capital costs, operating costs, make-or-buy decisions, alternate methods of production, and varying rates of production are among the activities included in the linear programming model. Examples of data involved, data gathering problems, problem formulation, output reports, and some of the typical management problems attacked are discussed.

C-1.4 Manufacture of a Product in the Face of Uncertain Demand, Phillip G. Carlson, *School of Business Administration, Tulane University, New Orleans, Louisiana 70118.*

Manufacturers of seasonal or other products are often faced with uncertain demand over a planning period. The objective is to take a position—or perhaps a sequence of positions—with respect to the demand in order to maximize expected profit. The approach is to develop a sequence of lot sizes based upon the usual setup and carrying costs plus the cost of residual units and the form of the imputed demand function. The operating procedure is to manufacture the lots in sequence as needed. The particular sub-optimal solution given here is where the lots are all equal and the imputed demand is rectangular. The procedure gives the manufacturer a decision rule for the best *maximum* number of runs to plan for and the length of each run.

C-1.5 A General Purpose Simulator for Forecasting Demand, Inventory Control and Production Scheduling, N. Benchkovsky, *Lybrand, Ross Bros. and Montgomery, MSC, R & D, 60 Broad Street, New York, New York 10004.*

The purpose of the simulator for forecasting demand, inventory control and production scheduling is to test different models in order to evaluate different approaches to forecasting, inventory and production management. The simulator will calculate average demand, forecast one, two, three and four periods ahead, trend tracking signal, reorder point, economic order quantity or economic quantity to manufacture, mean absolute deviation, safety stock, forecast plus safety stock, unusual demand, and seasonal indices for each month. The simulator is a general purpose simulator. It can handle several seasonal routines as well as non-seasonal routines. It also incorporates slow moving routines and a number of initialization routines. Seasonal indices can be generated automatically, starting with a base of 1.00 for each month or starting from any other base. Any values can be assigned to the smoothing factors. Because of the number of variables that can be handled, the number of variations that can be run through this simulator is in the thousands. Output reports contain several criteria for evaluating the efficiency of each set of combinations of factors or conditions used in a simulation. The value of the mean absolute deviation, the tracking signal and safety stock, are calculated each month, the coefficient of variation, which measures the efficiency over the whole test period, is calculated at the end of the test period. The simulator, for example, can be used to demonstrate to management the effects of various decisions that can be made. For example: the effects of varying customer service levels on inventory investment or the effect of changing reorder quantities on lead times.

C-1.6 Dynamic Programming Approach to Disposable-Reparable Inventory, E. G. Hurst, Jr., *Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

With one notable exception, little work has been published on the realistic inventory situation where repair of unserviceables is an alternate source of supply and where disposal of unserviceable and ready-to-issue inventory is permitted at every stage. The current paper presents an extension of the usual dynamic programming inventory formulation in this direction. A quite general end-of-period loss structure and demand-return joint distribution are permitted. Proportional ordering and disposal costs are assumed. A dynamic programming formulation is obtained with two state variables representing the two kinds of inventory and two decision variables representing the desired levels of these inventories. A policy structure at every stage is derived from this functional equation, and it is shown inductively to be the optimal policy. A brief discussion of possible extensions is given, in particular the possibility of including an ordering set-up cost.

C-1.7 Marketing Techniques and Corporate Modeling, Henri L. Beenhakker, *Stanford Research Institute, Menlo Park, California.*

During the last ten years, there has been a mounting outpouring of literature about O. R. approaches to marketing. The collection of published articles is incoherent as each deals only with a limited number of marketing elements. Furthermore, few have yielded useful (implemented) results. This paper surveys the significant articles and discusses successful applications of O. R. techniques to marketing. The O. R. techniques applied to marketing are classified in order of the degree of structure. The classification is: (1) planning check lists, (2) logical analytic frameworks, (3) adaptive search approach, (4) heuristic problem solving, (5) systems simulation, (6) rhocrematics, (7) mathematical models, (8) statistical techniques, and (9) conventional optimizing techniques. The paper investigates which of these nine techniques have been widely used, used by leading market analysts or have potential for future use in the analysis of the following marketing elements: (1) product planning, (2) pricing, (3) branding, (4) channels of distribution, (5) personal selling, (6) advertising, (7) promotions, (8) packaging, (9) display, (10) servicing, (11) physical handling, and (12) market research. Limitations, assumptions and cost benefits of each of the techniques are examined. Special attention is given to the place of these techniques in corporate models.

C-1.8 Maintenance Parts Logistics—A Simulation Approach, S. FIELDEN, *International Business Machines Corporation, Field Engineering Division, Poughkeepsie, New York.*

Maintenance time and service quality in the computer field are directly influenced by the ready availability of replacement parts. The logistics problems, however, are formidable in light of a need for hundreds of different stocking locations to be used for stocking thousands of part numbers, to be available for use in hundreds of different machine types at thousands of customer sites when, in fact, parts failures cannot be predicted exactly as to time, place, or quantity. Subject to financial and service quality constraints, the problems have been reduced to determining which inventory control system and initial stock levels should be used a) when reorder control is assigned to the stocking location or, b) when reorder control is assigned to a remote control computer facility. The total problem environment was subdivided into four classes with appropriate stochastic simulation models being developed for each class. Depending upon whether the class represented a single part of multiple parts and a single stocking or multiple stocking locations, such concepts as echelon stocking, cluster stocking, and response to obsolescence can be studied for optimization. The stochastic simulation models, thus far constructed, incorporate such features as real time control, variable work week lengths and individual availability of all facilities, the interaction of the information delay system and the product delay system, a statistical reorder decision function, variable reporting periods, variable reorder policies, and self-optimization of the inventory control policies. Though the work in this area is expected to continue for some time, the completed models exhibit the ability to identify maintenance parts logistics policies which appear to be financially and service-wise desirable.

C-1.9 A Markovian Approach to Evaluating New Bank Services, GERALD G. WISZ, *Marine Midland Corporation, 241 Main Street, Buffalo, New York 14203.*

The banking industry is currently faced with the problem of determining a priority list for the development of new computer-based customer services. The construction of such a priority list requires the reduction to a single measure of the significant factors involved in the evaluation of a specific service. The author considers the following four factors as significant, namely: (1) the costs, (2) the market, (3) the competitive situation, and (4) some measure of profitability. The reduction of the latter factors to the basis of the expected profitability of a service as a function of time is provided for in this paper through an analytical framework which utilizes the mathematical techniques of Markov processes. A first order absorbing Markov chain is proposed as a system which can quantitatively encompass the aforementioned significant factors. The Markov model is applied to the payroll service offered by a typical bank. An estimation of the transition matrix for the model is obtained through a sample of fifty firms. Various statistical tests are applied to the sample data to test certain hypotheses about the transition matrix. An extension of the Markovian model in which a new service is viewed as a project competing for a bank's investment is also explored.

C-1.10 Profit Maximization in Incentive Contracts, WILLIS A. SOPER, JR., *Raytheon Company, Bedford, Massachusetts.*

Incentive type contracts are occupying an increasing percentage of contracts awarded by the Department of Defense. The purpose of this type of contract is to provide profit incentives to contractors to produce for the customer higher performance end items at lower cost in a shorter time. A distinction must be made between: (1) the establishment of incentives before contract award, and (2) the choice of incentives or strategy during the execution of the contract. In the former, target cost, performance, and schedule are negotiated by the customer and contractor. Ranges of these factors are established in accordance with customer indifference criteria and willingness to trade off cost, performance, and schedule. Variable profits are associated with these factors in accordance with existing regulations or practices and estimates of the worth to the customer of different cost, performance, and schedule. After award of the contract, management must choose that combination of cost, performance, and schedule which will maximize profit. This decision is difficult to make because of the interaction of these three factors and because of the uncertainty of attaining these goals. This paper develops a procedural and analytical approach to this decision and describes the associated risks. An actual case study is presented.

C-2.1 Basic Review of PERT/CPM Technology, GLEN SELF, *Department of Industrial Engineering, Texas A&M University, College Station, Texas.*

The present status of CPM and PERT will be reviewed in order to provide a background for the more specialized papers to be presented in this session. The various common aspects will be discussed for the two methods in an introductory manner. The points which will be discussed include: (1) common methods used in the derivation of networks, (2) methods used in adjusting the network, (3) the specification and use of probability distributions in PERT, (4) critical paths and slack in networks, (5) benefits attributed to the use of PERT, and (6) problems associated with the application of PERT. Though general, this discussion will provide the uninitiated with a basic understanding of the concepts and the experienced user with a brief review.

C-2.2 A Unified Planning and Scheduling System, R. W. METZGER *and* R. E. THIELE, JR., *The Dow Chemical Company, Midland, Michigan.*

A Unified Planning and Scheduling System (UPSS) has been developed which provides a complete system for project planning and scheduling. The UPSS system includes the network planning techniques of PERT and CPM and heuristic techniques for resource leveling or scheduling. The statistical characteristic of PERT and the minimum cost time compression characteristic of CPM are available to the system user at his option. PERT and CPM are planning tools—they establish the limits for scheduling, but are, in general, ineffective for solving the problem of resource requirement vs. availability. The heuristic techniques, included in the scheduling part of the system, provide a good schedule of activities within the resource availabilities. UPSS is designed for both the expert and the occasional user with simplified input and meaningful output—output designed for the project manager. Several applications will be discussed in detail to illustrate the various uses of UPSS for project planning and control. These include a plant turnaround, in which the sum of expediting costs and outage costs were minimized; another plant turnaround, where extra men rather than cost were used for time compression; the scheduling of courses in an engineering curriculum; and several generalized networks for product research and development.

C-2.3 A Total Systems Approach to PERT-CPM, B. U. MILLER *and* D. E. MILLER, *Autonetics, Anaheim, California 92803.*

A persistent challenge encountered in the application of a management system based upon PERT-CPM has been user understanding and acceptance. Characteristically, useful results are not realized until proper balance is maintained between several conflicting areas of management concern. Modern companies are faced with more than a need to identify product cost and schedule problems; equally important are the requirements of the internal accounting system and the need to allocate human resources efficiently within a complex organizational structure. For the past two years an operations research team at North American Aviation's Autonetics Division has developed a low cost and uniquely simple, yet comprehensive, automated management system known as SCOPE. Today, Autonetics is enjoying the successful implementation of SCOPE; the system is providing valuable information to all levels of management for routine participation in such areas as organizational performance, schedule and cost status on product/program development, organizational and program manpower requirements, and allocation of human resources with incumbent organizational change. This paper will describe the capabilities of SCOPE, emphasizing the difference and advantages of this system to other management systems and its flexibility to permit rapid, practical implementation in other firms.

C-2.4 Networks for Multi-Project Operations, JOHN E. STACY, JR., *Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri.*

(No abstract available.)

C-2.5 Project Scheduling With Limited Resources, JEROME D. WIEST, *Assistant Professor of Production Management, University of California at Los Angeles, Los Angeles, California 90024.*

Present PERT-type scheduling models implicitly assume unlimited availability of resources. When resources are limited, however, the concepts of "slack" and "critical path" lose their normal meaning, as activities may be constrained in their start dates by availability of resources as well as technological orderings. Analytic solutions to the limited-resource, project scheduling problem are infeasible; heuristic approaches seem most promising of useful results. One such approach, described here, is a computer model capable of scheduling single or multiple projects within resource limits and other constraints commonly encountered by the project scheduler. The model is based in part on the concepts of "critical sequence" and "conditional slack," derived from a limited-resource modification of network scheduling methodology (reported in *Operations Research*, May–June, 1964, pp.

395–418). These concepts are discussed, along with the basic formulation of the model and its scheduling heuristics, which determine the period-by-period allocation of resources to activities in a project. By changing certain parameters and heuristics in the model, one can simulate project scheduling under varying constraints and scheduling rules.

C-2.6 High-Speed Calculation of the Critical Paths of Large Networks,

MICHAEL MONTALBANO, *IBM Systems Research & Development Center, 2670 Hanover Street, Palo Alto, California 94304.*

For large critical-path networks, most existing computer programs require separate tape passes to perform such functions as *topological sorting, consistency checking, forward time calculation, backward time calculation, loop tracing,* and so on. This paper describes a working program on the IBM 7090 which performs all of these functions in one pass. The amount of computer time required for the calculation depends both upon the size of the network and the number of arcs in the path of longest arc-length. For a network of 3000 nodes (activities), 21,000 arcs (precedence relationships) and 100 arcs in the path of longest arc-length, the calculation of early and late start times, critical path, and floats required less than six minutes. The basic algorithm occupies a relatively small portion of core memory. If it were separated from the input-output routines, it would permit the calculation, in one pass, of even larger networks (of the order, for example, of 7500 nodes and 37,500 arcs). Work on an even faster, more flexible program is currently under way.

C-2.7 Automatic Computer PERT-CPM Plots,

D. E. DALLIN, *University of Utah Computer Center, Salt Lake City, Utah.*

A computer program has been developed which will automatically plot PERT-CPM networks. The input consists only of prerequisite activity data, and the final size of desired plot. The computer program sorts the activities into time-sequence, then produces a well laid-out PERT-CPM plot of the activities. Node circles are located, activity lines are drawn to connect the nodes, and finally, each activity line is labeled. The computer program, written completely in FORTRAN IV, will operate on a medium size computer. Required computer time is minimal. A typical total cost for doing a computer plot is about five to ten cents per activity. The CalComp digital plotter is used to produce the plots. The program makes available to the operations research analyst a very new, powerful tool. He is now able to lay out his PERT-CPM prerequisite activities, and almost immediately obtain a plot of the network. This will aid him in further analysis, and will always reflect the latest network configuration. Typical plot problems were considered and largely solved in designing an automatic PERT-CPM program. Examples of the problems are node layout, uncluttered activity lines and labeling. The paper discusses these problems and several examples of plotted networks are included.

C-3.1 Solving Large-Scale Systems,

GEORGE B. DANTZIG, *Operations Research Center, University of California, Berkeley, California.*

Many important applications require the solution of truly enormous linear programs. Alternative methods of solving systems with special structure such as dynamic block angular and sparsely connected systems will be discussed. Proposals of Beale, Rosen, Bennett, Van Slyke, Wolfe and the author's and others will be reviewed.

C-3.2 Computational Aspects of Large-Scale Quadratic Programming Problems, ANDREW WHINSTON, *University of Virginia, Charlottesville, Virginia.*

The computational aspects of quadratic programming problems will be surveyed. Particular attention will be given to large-scale problems and their reduction to computable form. In particular, decomposition type algorithms will be discussed. The question as to the efficiency of pivot selection rules will be posed and some attempts at answers will be given. A discussion of the relationship of the size of a quadratic problem and the ordering of the pivot rules will be presented.

C-3.3 Applications of Column and Row Generating Techniques, RALPH E. GOMORY, *Thomas J. Watson Research Center, IBM Corporation, Yorktown Heights, New York.*

Applied problems with a great many columns or a great many rows can often be dealt with by decomposition-like methods if the rows or columns have a systematic origin. Application to production planning and network design will be discussed in which the columns are produced by dynamic programming, network flow calculations, etc.

C-3.4 Delayed Data Generation: Experience and Prospects, RICHARD H. COBB, *Mathematica, Princeton, New Jersey.*

Many special methods of solving mathematical programming problems all using the simplex method have been devised since 1958 to handle large problems. All these methods generate the necessary data only if it is required. All these approaches can be grouped into one class and called delayed data generation methods as summarized by Michel Balinski. The paper will survey computational experience with delayed data generation methods. This will include experience with Dantzig-Wolfe decomposition (with several types of subproblems), integer programming, stock cutting, and job lot scheduling problems. Observations will be summarized and lead naturally into a statement of the guiding concepts that should be applied in designing the next generation mathematical programming codes.

C-3.5 Finding Permutation Operations to Produce a Large Triangular Sub-Matrix, J. C. DICKSON, *Bonner & Moore Associates, Inc., 500 Jefferson, Houston, Texas.*

When computing the product form of the inverse of a sparse matrix, the sequence of pivots selected for the calculations can have a marked effect on the number of non-zero elements in the inverse. If the permutations required to produce a large triangular sub-matrix are known, this information can be used to produce an inverse in product form which is very sparse. This paper describes a procedure for determining the permutations which would produce a large triangular submatrix. It has been successfully implemented in the UNIVAC 1107 LP2 system. The procedure described has several interesting features: (1) examination of the matrix proceeds column by column, (2) only three passes through the matrix are required, although four passes have proved beneficial in some cases, and (3) the matrix does not have to be square. The last feature is particularly advantageous when an inversion is being performed as part of a CRASH operation in linear programming. Results on several problems are presented to illustrate the effectiveness of the technique on different problem types.

C-3.6 Large Scale Nonlinear Programming, ANTHONY V. FIACCO, *Research Analysis Corporation, McLean, Virginia, and Northwestern University, Evanston, Illinois, and* GARTH P. MCCORMICK *and* W. CHARLES MYLANDER, III, *Research Analysis Corporation, McLean, Virginia.*

For the general nonlinear programming problem (nonlinear constraints, nonlinear objective functions) the difficulty of obtaining a solution is controlled by n, the number of problem variables. This is in contrast to linear programming (where non-negativity requirements are always assumed) where m, the number of nontrivial constraints, determines the size of problems that can be handled and their speed of solution. This paper outlines in detail modifications to the Sequential Unconstrained Minimization Technique (SUMT) [MANAGEMENT SCIENCE, Vol. 10, No. 2, January 1964, pp. 360–366] for nonlinear programming which expand the size of problems that it can solve to the limitations imposed by the special case algorithms devised for them. In particular, the special cases of mathematical programming, i.e., linear programming, separable programming, "factorable" programming, and nonlinear partitioned programming will be described. Examples, and the implementation on a large buffered computer system will be discussed.

C-3.7 Some Special P-Models in Chance-Constrained Programming, A. CHARNES, *Northwestern University, Evanston, Illinois, and* M. J. L. KIRBY, *Research Analysis Corporation, McLean, Virginia.*

This paper is concerned with the complications engendered by the imposition of the nonlinear *P*-functional (in the terminology of Charnes and Cooper) instead of the *E*-functional in chance-constrained programming. Various modifications of the standard chance-constraints are also studied. The work focuses on special structures called "triangular P-models" and develops characteristics of optimal decision rules.

D-1.1 The Hopefulness Syndrome and Long-Range Planning, BERNARD N. SAMERS, *Management Research and Consulting Division, Dunlap and Associates, Inc., 123 High Ridge Road, Stamford, Connecticut 06905.*

There has been in recent years increasing application of management science to the planning process. Most of these applications can be characterized as deterministic or "stochastically stable." The real world, however, is, in man's experience, an unstable environment; and the manager is faced with decisions, not under uncertainty (stochastic risk), but under "cataclysmic" change. The wishful thinking that is concomitant with planning for a stable environment might be characterized as the "hopefulness syndrome." This paper attempts to describe how planning should be accomplished in the face of instability. It discusses the fundamental purposes, functions, and characteristics of the planning process; highlights the weakness of the ordinary stochastic planning processes, such as PERT, decision trees, etc.; and suggests a complete recasting of the planning process which utilizes management science in management-oriented terms.

D-1.2 The Metropolitan Data Center—A Key Tool for Local Planning,

ROBERT L. WEGNER, SR., *Tulsa Metropolitan Area Planning Commission, 600 Kennedy Building, Tulsa, Oklahoma 74103.*

A continuing comprehensive planning process in local government requires frequent and often extensive manipulation of large masses of detailed data. To meet this problem local planning agencies are beginning to employ OR, computer technology and systems analysis. One of the most comprehensive efforts to develop an effective system for planning data management has been the Metropolitan Data Center (MDC) Project. In this recently completed study five city and metropolitan agencies cooperated with the Urban Renewal Administration in developing, testing and evaluating a centralized data system for collection, storage and retrieval of general planning data. These systems are now operational in Denver and Tulsa. A separate special system, also operational, was developed in Wichita to help determine capital improvement project priorities. Problems encountered and guidelines derived from this study can assist others develop similar systems and also indicate where further effort is needed. To help urban and metropolitan planners develop workable data systems, the American Institute of Planners has established a Committee on Information Systems. This committee has inventoried both data retrieval and bibliographic retrieval systems now being developed or used by planners. The committee is enlisting the cooperation and assistance of specialists in OR and other fields to develop new tools for local planning.

D-1.3 Application of Heuristic Gaming to Urban Problems,

RICHARD D. DUKE, *and* BARTON R. BURKHALTER, *Institute for Community Development, Michigan State University, Lansing, Michigan.*

Computer simulations have been applied with increasing frequency in recent years to a wide variety of urban problems, most notably for the land use and transportation elements of comprehensive plans. The increasing elegance and sophistication of these simulations has tended to widen the communications gap between the technicians who develop them, and the non-technically oriented decision makers for whom their output is intended. Heuristic gaming, a technique which had its origins in early war gaming efforts, is a possible device for overcoming this barrier. Designed as a man-machine communications linkage, heuristic games are a convenient flexible technique which have the capacity to demonstrate to appropriate human decision makers the consequences of alternative decision change on metropolitan growth patterns through the use of a simulated, abstracted environment, employ a reduction of time span and dynamic interplay of current decisions with fixed policies. They are designed to: (1) illustrate the kinds of information which are available to decision makers, (2) inform the decision makers about the techniques which are available to evaluate and implement decisions, and (3) provide information concerning the implications for urban development which are associated with alternative courses of action.

D-1.4 Transit Service Optimization, Robert S. Scott, *New York State Office of Transportation, Box 7023, Albany, New York, and* Charles R. Guinn, *Bureau of Planning, New York State Department of Public Works, State Campus, Albany, New York.*

A technique has been developed to select an optimum route structure and schedule for both peak and off-peak time periods to meet selected objectives. Examples of such objectives are maximization of profit, maximization of usage, and maximization of non-subsidy service. The technique utilizes an operational computer program for optimizing integer linear programming problems. Inputs to the computer program include those derived from a modal-split model developed by C. R. Guinn over the past two years. Utilizing these inputs along with a suitable set of restraint equations, the program is able to optimize such functions as transit service, transit usage, or transit service with a specified amount of subsidy and to predict future transit usage resulting from proposed transit improvements. This technique is used to evaluate existing transit systems and plan new systems by comparing the existing or proposed system with the optimum system. One specific use of technique is to determine the true cost of various transit policies. For example, cost of providing a minimum level of transit service in a specific section of the urban area is determined. This information gives the policy maker a greater insight into the merits of a specific transit policy. Responsible use of this technique should remove some of the emotions which cloud the evaluation of a balanced urban transportation system.

D-1.5 Planning for Optimal Water Resource Development, Charles S. Beightler, *and* Wilbur L. Meier, *College of Engineering, The University of Texas, Austin, Texas 78712.*

This paper discusses the applications of recently developed analytical techniques to the problem of planning for optimal water resource development. An optimal plan with regard to the size and location of proposed reservoirs is that physical configuration which provides the greatest net economic benefit to the people of the region while meeting anticipated future water needs. Optimizing a water resource system is not an easy task, since the output from each reservoir provides an input to all downstream reservoirs, and the streams themselves form branched inputs to one another. In the present study, algorithms are used to decompose the branched system into equivalent serial systems which are then amenable to analysis by the serial optimization techniques of dynamic programming. Since water is a limited resource, and our population is expanding rapidly, this planning represents a vital problem of immense proportions; Texas will spend several billion dollars on reservoir construction in the next two decades. Development decisions of this type are made largely by subjective means at the present time, and there is little uniformity in reservoir planning. The interaction analyses presented in this paper provide methods of solution to water development problems which allow for uniform and objective decisions.

D-1.6 Municipal Planning for Wartime Emergencies, WALTER D. WOOD *and* ROBERT J. FLANAGAN, *The Dikewood Corporation, Albuquerque, New Mexico.*

Federally furnished information can be used as guidance for municipal planning to counter effects of nuclear attacks. Analysis methods for deriving individualized plans for emergency operations are discussed. Vulnerability reduction using prepared and improvised shelter and population movement are compared and problems presented by fire and fallout are described.

D-1.7 A Cost-Effectiveness Computer Procedure for Optimum Allocation of Fallout Shelter System Funds Under Uniform or Variable Risk Assumptions. EDGAR A. PARSONS *and* FLOYD M. GUESS, *Research Triangle Institute, Post Office Box 490, Durham, North Carolina.*

A model has been developed to assist Office of Civil Defense research staff and planners in evaluating expenditure policies and procedures for implementing a national fallout shelter program. The model has been programmed for a CDC 3600 computer in such manner as to facilitate computations using different parameters. The objective of the computer model is to allocate Civil Defense funds to areas of the nation (e.g., states, counties, and smaller areas such as census tracts) in a manner which will provide maximum protection for the population against the radiological environment caused by nuclear attack. The allocation takes into account the fallout shelter needs of each area as determined from an estimate of the risk in each area and the existing protection against fallout. Given a set of identified options and costs for satisfying these shelter needs, an assumed sum, or preparedness budget may be allocated among areas in a manner which maximizes a measure of effectiveness such as survivors added or casualties avoided for that specific fund of money.

D-2.1 CPM-PERT Scheduling for a Large Industrial Project, C. K. JHA, *Scientific Management Services, Lester B. Knight and Associates, Inc., 549 W. Randolph, Chicago, Illinois 60606.*

The Critical Path Method though simple in concept becomes exceedingly difficult in application. This is particularly true in a civilian project where the compliance with the requirements of CPM scheduling by contractors is rather loose. The burden falls on the CPM planner who must not only develop a realistic network, but must also be able to educate, sell his ideas, be flexible and insist on compliance where necessary. Such heavy tasks can be successfully performed only through generation of realistic control reports. A simulation model to learn problems of generating various control reports for controlling a multi-million industrial plant where the number of activities is expected to exceed 20,000 was constructed and tested. Based on the valuable experiences gained, the standard PERT-Cost Program is currently modified to suit the specific control requirements. The project is currently being controlled from design phase to construction phase by CPM scheduling.

D-2.2 Evaluation of R&D Projects Using Network Planning Techniques, COL. I. JACOB, *Military P.O. Box 2154, Tel-Aviv, Israel.*

In the evaluation of a military R&D project in the early definition stages, three parameters are in consideration: performance, cost, and time. Evaluation of expected cost and lead time of the project can be based on PERT techniques, while there is no known formal method to incorporate the third parameter, performance, into the evaluation process. The paper describes a method for such an evaluation in the following manner: (1) breaking down a proposed project into attributes, and defining the influence of each attribute on the performance of the final product, (2) elimination of unfeasible and unfavorable performance outcomes using a systematic process, (3) building time and cost CPM networks related to each performance level, (4) processing the above, using the CPM algorithm, getting Time-Cost curves for each performance level ("Performance Maps"), and (5) the decision maker, by choosing any point on the performance map, defines explicitly his choice for quality, cost, and lead time of a project. Choosing different performance levels and relating to each its Time-Cost curve is programmed on a computer. A PERT-like input is fed in, with some additional information, and upon processing one gets the "Performance Map". The method was initiated in a M.Sc. thesis by the author in the M.I.T. Sloan School in 1963, and was tried and improved in work done later on. The paper describes the method, its usefulness and limitations.

D-2.3 Application of PERT to Financial Month-End Closing Procedures, CARL A. PALLO, *Anaconda Aluminum Company, P. O. Box 1654, Louisville, Kentucky 40201.*

An account is given of the application of the PERT-Time technique to a corporate month-end closing procedure. The network includes all financial sections and includes sub-networks for scheduling the functions associated with data processing. Total closing time was reduced from 16 to 8 days.

D-2.4 Using PERT-CPM as an Aid in Planning and Managing New and Complex Medical and Surgical Procedures, JOHN M. LONG, WILLIAM J. FLANIGAN, *and* MASUKI HARA, *University of Arkansas Medical Center, 4301 West Markham Street, Little Rock, Arkansas.*

Many of the newer modalities of medical treatment are quite complex involving several parallel activities, requiring close coordination of many people and fairly precise timing. It would appear that computerized planning and management techniques would be helpful in planning for these new and complex procedures such as organ transplants and open heart surgery. This is especially true in planning and preparation for the first application of a new type of surgery. The authors have attempted to evaluate PERT-CPM to ascertain whether this technique would be useful. The technique has been applied to renal (kidney) transplantation. The results of the PERT-CPM schedule are compared to the operational procedure developed by experience. The results suggest that PERT-CPM may be useful in future planning of new medical and surgical techniques.

D-2.5 The Voluntary Application of PERT in a Commercial Research and Engineering Development Program, M. POLOMOSCANIK, *Current Planning Department, Xerox Research and Engineering Center, Webster, New York.*

PERT is normally applied in government programs, but Xerox Research and

Engineering has *voluntarily* adopted PERT in what is currently the Company's most important *commercial* program—design and development of the new Xerox 2400. The history and use of PERT at the operating levels are described, from the initial machine design, through the engineering and prototype models, through the completion of the engineering drawing stage, even to the "downstream" planning activities. Included is a discussion on the training of operating personnel, implementation of PERT techniques, and the role played by the support organization. In addition to the use of PERT in the 2400 program, Xerox applies the technique to several other non-governmental programs, including one in which Telex is used for what is probably one of the first attempts at intercontinental transmission of PERT information.

D-2.6 Critical Path Scheduling: Tableau Method, James L. Riggs *and* Michael S. Inoue, *Department of Mechanical and Industrial Engineering, Oregon State University, Corvallis, Oregon 07331.*

C.P.S. Tableau Method is a practical technique associated with a Table-Matrix format which may contain all information necessary to compute time schedule and to construct various graphical representations for critical path analysis, such as: arrow network, bar chart, time chart, and manpower diagram (a useful tool for resource allocation). The Tableau algorithm is totally activity-oriented and requires no numbering of nodes or preliminary plotting of sequential relationships in graphical form. For example, it is no longer necessary to draw a graphical network to determine critical paths or any other path that may be of interest. Though the Tableau Method could generate "Free Float," a more useful "Independent Float" is found for each activity in addition to its "Total Float." C.P.S. Tableau has been found to provide more efficient algorithm for computer program over traditional programs by eliminating the need for node numbering. As a manual method, it can also serve as a compact historical record as well as a conventional planning tool. The applications of Tableau can further be extended to assist in allocating equipment, leveling manpower assignment, and to find time-cost curve by means of a Dual Network. Simple Dynamic Programming problems such as the "Travelling Salesman Problem" may also be solved by means of this Tableau.

D-2.7 Project Cost Curves, Some Equivalent Graph Theorems, V. K. Handa, *Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada.*

To provide a better understanding of the process of determining project cost curves for CPM networks, further linear graph theorems are presented. When applied to equivalent linear graphs of CPM networks, it is possible to obtain the project cost curve without the aid of a computer, in the case of medium sized projects.

D-2.8 Optimal Resource Allocation in Activity Networks, P. M. Ghare, *Industrial Engineering, Texas Technological College, Lubbock, Texas.*

This paper describes an activity network model based on the assumption that the duration of an activity can be controlled by the modification of resources allocated to the activity. This was achieved by expressing the two principal variables (the resource allocation for an activity and the time required for its completion) as the through variable and the across variable of the system, respectively. Having defined the through and across variables of the network, the techniques of system theory are used to express the network relations in a minimum number of equations. These equations are then used to optimize the allocation of limited resources between alternative activities with the objective of minimizing the total time required for the execution of the project. An algorithm based on this model is also described which enables the transformation of a problem of resource allocation into a mathematical programming problem. It was shown that by considering the duration of an activity as a variable under the control of management, an enlarged activity network model can be developed. This model can be used to optimize the allocation of scarce resources among competing activities of a project. The use of the algorithm presented was also shown to be feasible in determining the resource allocation policy. In addition, it is concluded that the concept of management control of activity duration enhances the usefulness of activity planning models.

D-2.9 PERT: Problems to Resolve, H. O. HARTLEY *and* A. W. WORTHAM, *Institute of Statistics, Texas A&M University, College Station, Texas.*

PERT and Critical Path techniques are enjoying exceptionally broad application in industrial and military activities. These techniques and their application have without doubt contributed significantly to better planning, control, and general organization of many programs. It has been noted, however, that the paths selected as critical by these techniques are sometimes not critical and that times determined for project completion are generally optimistic. In this paper these deficiencies are assessed, their magnitudes estimated and corrected. Both analytic theory and numerical analysis are used to achieve this but in certain situations approximate evaluations by Monte Carlo have to be made. Moreover, a new classification of PERT networks is presented along with two methods of analysis which do not have the deficiencies noted above. The classification system delineates clearly between 'uncrossed', 'crossed', and 'mixed networks'.

D-3.1 A Cost Sensitivity Analysis of Major Design Characteristics of GHOST and SCOMO Meteorological Systems, ROBERT M. CARLISLE, *Systems Analysis Department, Bendix Systems Division, Ann Arbor, Michigan.*

An analysis is made of the sensitivity of system costs to changes in design and operational characteristics of a satellite system designed to relay data from: (1) a global network of free-floating meteorological balloons (GHOST), and/or (2) a network of sea and land based meteorological stations (SCOMO). The data would be relayed in a timely manner from satellites to ground read-out stations and, in turn, to a central data processing station for analysis and dissemination. Total system costs were developed for each system design alternative. Included in these costs were research and development, initial investment, and annual operating costs. When total system costs are derived as a function of major system design variables, a determination is made of those design parameters to which system costs are most sensitive. Those design characteristics which have the most significant effect on system costs are: (1) the balloon replacement rate in the GHOST system, (2) the reliability of the satellites, and (3) the unit production cost of the balloon and balloon electronics, which is treated as a variable in view of the rapidly changing state-of-the-art in the electronics and power supply system. Recommendations are set forth for determining those design and operational characteristics which serve to minimize total costs for both the GHOST (Global Horizontal Sounding Technique) and SCOMO (Satellite Collection of Meteorological Observations) systems. The ultimate desirability of acquiring and operating such systems is explored by comparing the costs of the systems with the possible economic and social benefits to be derived from a better understanding of meteorological phenomena and the availability of more accurate and timely meteorological information.

D-3.2 **Rating of Race Horses' Performance,** Robert A. Porter, *Spindletop Research, Inc., Lexington, Kentucky 40505.*

The "profit" in breeding thoroughbred horses is to produce good performance on the race track. Objective studies of breeding theories require quantitative evaluation of this performance. A technique is developed for obtaining numerical ratings of race horses based on actual performances in races, with the biases due to different weights, different post positions, and different caliber of competition removed. Other uses of the ratings are also discussed.

D-3.3 **Generalized Models for Allocating Demographically-Dependent Manpower Resources,** Jacob A. Williams *and* William L. Moog, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland 21235.*

Workload inputs to the district office complex of the Social Security Administration consist of many different types of claims for benefits filed under the various amendments to the Social Security Act. The incidence of particular types of claims at any office is dependent on the local demographic composition. The work loading is then dependent on the mixture of cases since processing time and complexity varies with each type of case. This paper discusses the basic structure of idealized models which relate age-cohort concentrations to workload volume and subsequently to manpower requirements. The idealized models will consider the following problem aspects: (1) steady-state and dynamic input-output, and (2) population-workload correlates. Finally, a practical model design is proposed that is an integration of historical workload curves and demographic techniques. Deviations from the idealized structure are analyzed.

D-3.4 **An Application of Inventory Methods to Evaluate Staffing Levels of Professional Personnel,** Sylvan Hack *and* Francis Ichniowski, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland 21235.*

A particular type of staffing problem is analyzed from the viewpoint of inventory methods. Use is made of several types of inventory models in an attempt to set the best staffing level, to establish measures of sensitivity, and to evaluate ongoing organizations. Redefinitions of measurements are made to allow the inventory approach. Charts are plotted to picture actual systems and the inventory models, and to demonstrate the effects of varying conditions on the systems. The methods employed are both analytic and simulative. The problem of particular interest is that of a varying, but reasonably predictable, workload to be handled by a constant-size work group. Overtime is allowable depending on costs and human factors. The level of the work backlog must be sub-optimized, subject to minimization of the variance of the backlog and the constraint of processing individual work units on a FIFO basis. A further consideration in this study is the determination of an indicator as to "when" and by "how much" with regard to use of overtime work.

D-3.5 Some or Uses of Binomial and Poisson Probability Distributions,

JOHN E. WALSH, *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California 90406.*

A number of operations research problems can be stated so that a sum of amounts of "worth" is of interest. Here, the occurrence or nonoccurrence of each of the amounts is determined by a random binomial event and these events are independent. By suitable development of the binomial events, the situation can often be such that the same amount is associated with each event. However, the probabilities of, say, occurrence are not necessarily even approximately equal. If these probabilities do not differ substantially, the distribution for the sum of worths can be approximated by a binomial distribution plus a correction term. Here, the "probability" of occurrence for the binomial distribution is the arithmetic average of these probabilities for the binomial events. A normal approximation can often be used when the number of events is large and this average probability is not near zero or unity. A Poisson approximation can frequently be used if the number of events is large and the average probability is known to be near zero or unity. The Poisson approximation is also usable for some situations where the random binomial events can be mildly dependent. These approximations can be very convenient for treating these problems.

D-3.6 Mean Value Estimation from Digital Computer Simulation,

A. V. GAFARIAN *and* C. J. ANCKER, JR., *System Development Corporation, Santa Monica, California.*

Terminating and non-terminating stochastic processes are studied. If digital simulation is used, either a time-slicing or an event-sequencing technique may be used to obtain an estimate of some measure (mean value in our case) of system performance. We consider the variance of the estimate to be the basic measure for determining the goodness of the estimate. Three points are examined: (1) unbiasedness of the estimate, (2) efficiency of the estimate, and (3) variance reduction techniques. For the non-terminating case a large class of steady state processes having a negative exponential covariance function is studied and curves and specific examples are derived. Replication is shown to be generally superior to increasing the length of a run. For the terminating case, a general expression for efficiency is derived and again replication is shown to be the superior variance reduction technique. All results are equally valid for discrete or continuous processes.

D-3.7 An Investigation of Decision Systems for a Complex Management Game, Robert B. DesJardins, *School of Business Administration, University of North Carolina, Chapel Hill, North Carolina.*

The management game which was used in this study consists of two distinct parts: the simulation of a complex economic environment and the simulation of a decision system for making the 200–300 decisions which are required for playing the game. The simulation of the economic environment was patterned after the Mark I version of the Carnegie Tech Management Game. However, the program was written so that the game would accept decisions from an external source, an internal decision-making policy, or any combination of external and internal inputs. The internal decision-making policy is a heuristic program which makes its decisions entirely on the basis of the information that is available to students when they play the game. The decision program operates at three levels: a policy formulation level, a controlling level, and an operational-decision level. The program includes a set of "management parameters" which are initially set by the experimenter but are modified by the decision program to adapt the policy to changing environmental conditions. Several versions of the policy program will be discussed and the results of using these programs for 5–10 year simulations will be presented.

D-3.8 Decision Networks: A Methodology for Evaluating the Future Payoffs from Technology Development Programs, Charles W. Foreman *and* Frank P. Mertes, Jr., *Analytic Services Inc., 5613 Leesburg Pike, Falls Church, Virginia 22041.*

Technical uncertainties and present values of future costs and payoffs should be explicitly considered when assessing how profitable a technology development program would be, if initiated. The methodology described in this paper does this by displaying in decision network form the various courses of action open to a decision maker and by incorporating estimates of probable technical successes in calculations of the present value of each choice. To demonstrate, the paper describes the results of an illustrative study in which several technological possibilities, each of which could lead to the development of an advanced launch vehicle in the TITAN III-C payload class, were examined. The study results are compared to results obtained from previous published analyses of the same problem. And while the cost and time estimates used in each were identical, the comparison shows that the inclusion of technical uncertainties and the use of present values of future costs and payoffs shift the break-even point from 100 to 250 cumulative launches.

D-3.9 Optimal Information Flow In An Organization, Sant R. Arora, *Mechanical Engineering Department, University of Minnesota, Minneapolis, Minnesota.*

For any healthy organization it is essential to have a good information flow within the organization. This paper is an outgrowth of an attempt to construct a theoretical framework which is suitable for studying problems dealing with the design of information flow networks. An organization is regarded as a Multi-Station control unit. A decision regarding a control parameter at any station is a function of the information fed to the station and these parameters in general affect the trajectory of the objective function of the organization. Effects of rate of information flow and of time lag are studied. The case of a multi-item inventory system with several warehouses is given as an example.

D-3.10 Simulation: A Decision Device for Resource Allocation, A. P. FEDDERSEN *and* W. D. O'GRADY, *Autonetics, 3370 Miraloma Avenue, Anaheim, California.*

The objective of a study recently completed in this area was the analysis of an electronic system assembly and test area comprised of a variety of automatic test consoles. The basic function of this test area included both the production and maintenance of electronic systems. More specifically, the purpose of the study was to determine the minimal requirements for personnel and equipment necessary to sustain a given system production rate. In this study, all physical attributes and features of the test and assembly area were described and put into the computer along with other data such as failure rates, expected rate of arrival of electronic systems, time sharing of test consoles, recycling of failed systems, work schedules, etc. The package of computer programs then simulated the operation of the test and assembly area for various intervals of time. Computer outputs provided: (1) indications of queues, (2) utilization of the various automatic test consoles, and (3) indications of excess manpower, indicating where problem areas existed. Data changes, easily initiated, were then determined on the basis of the results and the simulation repeated to discover improvements in the production line. The end result of the study was recommendations to Management for corrective measures and automatic test equipment purchase. It is realized that simulation on a large scale computer is not a panacea for the problem of resource allocation; however, simulation techniques are rapidly gaining prominence as one of the major tools to support the decision processes in a complicated technological society.

D-4.1 The Zero One Problem, HARVEY GLASS, *Washington University, Department of Applied Mathematics and Computer Sciences, School of Engineering and Applied Science, Saint Louis, Missouri 63130.*

The zero-one integer linear programming problem may be described as a linear programming problem with the additional restriction that the independent variables may assume only the values zero or one. The application of dynamic programming to this problem is in some respects attractive. The discrete nature of the variables is a distinct advantage and the linearity of the problem insures that we require only the operations of addition and subtraction for computation. The difficulty lies in the storage needed for the dynamic programming formulation. Storage requirements grow exponentially with the number of constraints of the zero-one problem and problems of even moderate size become impractical on even the largest machines. The proposed algorithm is designed to trade additional computation time for a reduction in storage requirements. The procedure is to solve several smaller dynamic programming problems in such a way that the solution to our original problem may be calculated in a finite number of steps. With this method storage requirements grow linearly with the number of constraints. The efficiency of the proposed method has yet to be explored for large problems but as new hardware is developed allowing us access to large memory at near core speeds, the new algorithm should enable us to solve problems heretofore impossible.

D-4.2 An Algorithm for Integer Linear Programming, Robert A. Cook *and* Leon Cooper, *Department of Applied Mathematics and Computer Sciences, Washington University, St. Louis, Missouri 63130.*

At the present time, the only available practical techniques for solving integer linear programming problems are those of Gomory. The authors have developed an algorithm which is fundamentally different. It is based on the idea of solving as a linear diophantine equation a constraint equation which is parallel to the objective function hyperplane, and then ascertaining if the original constraints and the diophantine equation have a common lattice point solution. Finding such a lattice point is equivalent to solving a set of linear inequalities for an integer solution. Methods for finding such a solution are discussed, and computational experience with the algorithm is presented.

D-4.3 Practical Methods in Integer Linear Programming, C. A. Traute, Jr., *and* R. E. Woolsey, *Computer Mathematics Division Sandia Laboratory, Albuquerque, New Mexico.*

This paper pertains, as the title implies, to the practical aspects of integer linear programming. As such, it deals only with known integer linear programming algorithms which have already been coded, or which, in the authors' opinions can be coded in a reasonable way. The object is to point out both the practical advantages and limitations of these algorithms as well as the availability of certain computer programs based upon them.

D-4.4 Operational Experience With a Mixed Integer Algorithm, Norman J. Driebeek, *Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts.*

Operational experience with a branch and bound mixed integer algorithm is discussed. The algorithm has been incorporated as a post optimal agendum in 3 computer codes. All problems submitted to these codes have produced feasible mixed integer solutions. Problems with up to 20 integer variables have been solved with proof of convergence onto the optimum mixed integer solution. Larger problems have produced valid mixed integer solutions, but proof that these solutions were optimum could only have been established with large expenditures of computer time.

D-4.5 Solution of Problems by the Method of Steepest Descent, K. E. Geib, D. S. Hague *and* E. E. Mason, *McDonnell Automation Center, P.O. Box 516, St. Louis, Missouri 63166.*

The Method of Steepest Descent is applied to the problem of optimal staging of processes governed by ordinary first order non-linear differential equations. New methods of handling inequality constraints and weighting functions are included. The program is capable of simultaneously handling up to fifteen state variables, six control variables, and ten terminal conditions. Discontinuities may exist in both the state variables and their derivatives. The program was developed for flight path studies, but is readily extended to cover problems in other fields by replacement of the basic differential equations. Examples of the application of the method to flight path optimization problems and to chemical reactor optimization problems are presented. The computer program used to obtain these solutions is described, and a discussion of some techniques used to ensure convergence to the desired extremal is included. A brief discussion of the problem of dimensionality and the related topic of weighting functions is also presented.

D-4.6 On Solving Calculus of Variations Problems with Constraints Using Gradient Techniques, P. L. ODELL *and* JAMES MEEK, *The University of Texas, Austin, Texas.*

Bryson, A. E. and Denham, W. F. in their paper "A Steepest-Ascent Method for Solving Optimum Programming Problems," *Jour. of Appl. Mech.*, June 1962, have formulated a technique for solving calculus of variations problems with terminal constraints. They and others have applied the technique with success to problems in aerodynamics. It is the aim of this paper to: (1) formulate several classical calculus of variations problems so that the Bryson-Denham technique is applicable, (2) discuss methods which allow the technique to be used when other than terminal constraints are imposed, (3) report empirical results concerning convergence properties of the technique, and (4) give rules for determining various weighting matrices basic to the technique.

D-4.7 Electric Utility Application of Linear Programming with Variable Cost Algorithm, JOSEPH K. FURST, *Operations Analysis Section, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Pennsylvania.*

One of the major costs in the operation of an electric utility is the cost of construction of service buildings to house the men and equipment necessary for construction and repairing of electric transmission and distribution lines. A question arises as to the determination of the most economical number, size, and location of buildings in an area serviced by the utility. The answer must be such that a balance is achieved between the costs associated with: (1) the number and size of buildings, and (2) the travel time to and from work sites. The size of any building, and thus its cost, is dependent upon the number of line crews assigned to it. Because of the non-linear relationship between building costs and building size, an algorithm must be added to the existing linear programming code so that during the iterative process of the solution the building costs will vary in accordance with the number of crews assigned. The use of linear programming with this new algorithm results in a practical solution which shows the optimum number, size, location, and area to be served by each building.

D-4.8 An Application of Linear Programming to the Optimization of Materiel Airlifts, S. P. GINDER, *Dunlap and Associates, Inc., 1050 31st Street, N.W., Washington, D.C. 20007.*

The technique discussed in this paper was developed by the author while working on the Headquarters, USAF Command Control System (473-L). Specifically, the model addresses the problem of optimizing the strategic airlift reallocation of prepositioned materiel to minimize time required in adjusting resource posture to meet new logistic requirements. The model used is an adaptation of the Transportation Algorithm to reflect aircraft performance over multi-leg flight routes. Direct measurement of the time required to airlift a given cargo is not as tractable as it initially appears to be. Reallocation of materiel by airlift introduces the unique considerations of aircraft performance. The cargo load an aircraft can carry is a function of the non-stop distance it must fly. Further, the time required to transport a given load over a given distance is a function of the flying speed of the aircraft. The problem has massive information processing and computational requirements which require digital computer application for practical solutions. Although the model was developed for military logistics management, it also has commercial application.

D-4.9 The Process Concept as a Basis for Simulation Modelling, PATRICK BLUNDEN *and* HOWARD S. KRASNOW, *IBM Advanced Systems Development Division, 2651 Strang Boulevard, Yorktown Heights, New York 10598.*

Corporate modelling requires the formal representation of complex, dynamic organizations. Simulation systems to aid model development in this context are usually based upon primitive building blocks (modules) which permit the user to develop models of arbitrary complexity. This paper discusses the role of the process—an independent element displaying status and behavior—as the basic unit in model formulation and in the construction of simulation experiments. The modelling of both economic systems and industrial operations is considered. The relationship of the process approach to difference equation and discrete entity/event techniques is examined, together with implications for computer simulation and requirements for a process-based programming system.

Society Affairs

THE ORSA COUNCIL MEETING

The Twenty-Seventh Meeting of the Council of the *Operations Research Society of America* convened at 6:10 PM on 5 May 1965 in Parlor C of the Statler-Hilton Hotel, Boston, Massachusetts, with George Shortley, *Vice President,* presiding. The following items are reported from the Minutes of that Meeting:

FUTURE MEETINGS:

No.	*Dates*	*Location*	*Chairman*
28	November 4–5, 1965	Houston	James A. Birdwell P. O. Box 8423 Southmore Station Houston, Texas 77004
29	May 18–20, 1966	Los Angeles	John E. Walsh System Development Corp. 2500 Colorado Avenue Santa Monica, Calif. 90406
30	October 18–19, 1966	Chapel Hill	George E. Nicholson, Jr. Department of Statistics University of North Carolina Chapel Hill, N. C.
31	May 31–June 2, 1967	New York	Gordon D. Shellard New York Life Insurance Co. 51 Madison Avenue New York, N. Y. 10010
32	Fall 1967	Chicago	
33	Spring 1968	San Francisco	(Joint with TIMS)
34	Fall 1968	Philadelphia	

ORSA MEMBERSHIP: As of 31 March 1965, there were 1590 *Members,* 2615 *Associate Members,* and 372 *Student Associate Members,* for a total membership of 4,577.

TIMS: A West Coast meeting for the Spring of 1968, sponsored jointly by ORSA and TIMS, was agreed to by the Council. The Fall Meeting 1965 will be held in Philadelphia chaired by Lee Rogin.

AAAS: Representatives are Ellis A. Johnson and W. E. Cushen.

SYSTEMS ENGINEERING CONFERENCE: The Society is co-sponsoring a Systems Engineering Conference at Case Institute of Technology on 18–19 October 1965 with the Systems Science and Cybernetics Group (IEEE) on 20–23 September 1965 in Chicago.

SECTIONS:

Transportation Science: A three day meeting is scheduled for New York with fifty papers to be presented. Proposed amendments to the By-Laws of the Transportation Science Section will be approved upon approval of the membership of this Section.

Cost Effectiveness: Authorized at October 1964 Council Meeting the Section is co-sponsoring a 3-day symposium.

Houston: Upon modification of the Section's By-Laws to provide for notification to the Section membership of the proposed slate of officers in sufficient time to allow for nomination by petition, if so desired, the Secretary was authorized to approve the Section.

North Texas: The North Texas Section was approved subject to modification of By-Laws.

Military Applications: When the By-Laws conform to requirements, the Secretary was authorized to approve establishment of a Military Applications Section of ORSA.

IFORS: Fourth International Conference on OR will be held 29 August through 2 September, 1965. Representative is Hugh J. Miser.

TREASURER: Retiring Treasurer John E. Walsh was accoladed for his service to the Society.

APPOINTMENT OF 1965–1966 COMMITTEES: The following Committee Chairmen were appointed by the President:

Membership Committee	Newton A. Ablahat
Publications Committee	Russell L. Ackoff
Education Committee	Charles D. Flagle
Nominating Committee	Paul L. Kingston
Lanchester Prize	Walter L. Deemer
Meetings Committee	David A. Katcher
Sections Committee	William J. Nemerever
Ethics & Grievance	George Shortley

The Council passed a motion acknowledging the fine work accomplished by the committee chairmen, members of their committees, and other positions held for the past year. In particular they are:

Education: B. Koopman, H. Wagner, R. Evans, C. Flagle, R. Howard, B. Saunders, R. Shephard, G. Symonds.
Lanchester Prize Committee: A. Mood, W. Deemer, J. Moshman
Meetings Committee: P. Stillson
Membership Committee: N. Ablahat, K. More, K. Yarnold, P. Carlson, M. Ash.
Nominating Committee: G. Brigham, L. Clark, J. Hetrick, P. Kingston, R. Shephard.
Publications Committee: R. Machol, A. Charnes, E. Cushen, S. Gass, A. Marshall
Sections Committee: R. Mirsky
IAOR Editor: H. Galliher
Representative to IFORS: H. Miser
Editor, Bulletin of ORSA: V. C. Hare
Representatives to AAAS: R. Gerard, E. Johnson

NEW MEMBERS: The Membership Committee reported its nominees for full Membership in the Society. A list of new Members elected is shown:

Elected Members at 27th National Meeting

Apel, James R.
Ballaseyus, Albert C.
Bamford, Harold E.
Bartfeld, Charles I.
Basile, John P.
Berkman, Herman G.
Billingsley, James D.
Black, James A.
Bothmann, John R.
Calden, Louis
Carr, Charles R.
Cerone, James R.
Cherkas, Barry M.
Cobb, Joseph R.
Colonna, Robert A.
Corcoran, Thomas J.
Crawford, William T.
Cummings, William J.
Datz, Israel M.
Dahlhaus, Frank J.
di Roccaferrera, Giuseppe M.
Dwyer, James T.
Fogelsanger, Donald K.
Fox, Peter D.
Frick, Roy K.
Fukuda, Yoichiro
Garcia, Juan M.
Garnholz, Maurice H.
Ginder, Samuel P.
Goldman, Thomas A.
Halpin, Byron M.
Harbaugh, Allan W.
Heilenday, Frank W.
Henshaw, William C.
Hoekstra, Djoerd
Horn, Herbert O.
Jacobs Jr., Sidney
Jha, Chandra K.
Johnson, Thomas
Jones, Paul E.
Karayalcin, Ibrahim, I.
Kaye, John
Kennerley, John A.
King, William R.
Kleinsteuber, G. Werner
Laderman, Jack
Launders, Gordon A.
Lind, Barbara B.
Linder, Roger W.
Lipstein, Benjamin
Locke, John W.
McMichael, Robert W.
MacKinnon, Allen J.
Martel, Robert J.
Matteis, Richard J.
Meng, Donald R.
Midlam, Kenneth D.
Miller, William T.
Millican, Raymond W.
Morgan, Dale L.
Morgan, James I.
Moss, David M.
Neuts, Marcel F.
Norris, Richard C.
O'Neill, Daniel D.
Pallo, Carl A.
Papanek, Walter J.
Paxman, Richard G.
Peace, Travis E.
Peters, Stefan
Pollock, Stephen M.
Porter, Robert L.
Rabe, Fred A.
Rath, Gustave J.
Rios, G. Sixto
Sardella, Vincent
Schaffer, Marvin B.
Sharpe, Terry H.
Silver, Edward A.
Smith, Monte G.
Smith, Spencer B.
Spangler, Charles B.
Stember, Jerome A.
Stewart, Donald I.
Stout, Thomas M.
Strassmann, Paul A.
Strell, Hyman
Stuart, John J.

Swanson, Leland M.
Ternow, Helmut G.
Tiede, Roland V.
Tiemann, Arthur E.
Tucker, Thomas R.
Valfer, Ernst S.
Volpatti, Robert C.
Voss, Robert G.
Walner, Arthur H.
Wasdyke, James T.
Weinstein, Iram
Weinwurm, George F.
Weir, W. Thomas
White, Robert R.
Williams, Paul J.
Wolfe, Harvey

MINUTES OF THE 1965 ANNUAL BUSINESS MEETING

The Thirteenth Annual Business Meeting of the Operations Research Society of America was convened at 5:10 pm, 6 May 1965, in the Georgian Room of the Statler-Hilton Hotel, Boston, Massachusetts, with the *Vice-President*, George Shortley, presiding.

The Minutes of the Twenty-sixth Annual Business Meeting were approved as printed in the Fall 1964 issue of the Bulletin.

The Report of the Treasurer was approved as printed in the Spring 1965 issue of the Bulletin (p. B–95 ff.).

On behalf of the Tellers, the Secretary announced the results of the election of Officers:

John F. Magee	*Vice-President/President-elect*
Joseph H. Engel	*Secretary*
Thomas E. Oberbeck	*Treasurer*
Ralph E. Gomory	*Council Member*
Herbert K. Weiss	*Council Member*

The Vice-President declared this slate elected and assumed the Chair as President.

The Secretary announced the establishment of the Houston Section and the Military Applications Section of the Society.

The President stated that because of illness of the retiring President, his report would not be made at this meeting; however, it will be published in the Bulletin.

The Meeting adjourned at 5:20 pm.

Joseph H. Engel
Secretary

COMMITTEE MEMBERSHIP 1965–1966

Membership Committee

Newton A. Ablahat, Chairman
Clinton J. Ancker, Jr.
Kenneth R. More
John H. Moss
Kenneth W. Yarnold

Publications Committee

Russell L. Ackoff, Chairman
Robert E. Machol
W. Edward Cushen

Education Committee

Charles D. Flagle, Chairman
Norman N. Barish

Jack R. Borsting
George Dantzig
Daniel Howland
Harvey M. Wagner

Nominating Committee

Paul L. Kingston, Chairman
Georges Brigham
L. P. Clark
Paul F. Dunn
Bernard W. Romberg

Lanchester Prize

Walter L. Deemer, Chairman
George E. Kimball
Alex M. Wood

Meetings Committee

David A. Katcher, Chairman
David M. Boodman
Emory Cook
Hugh J. Miser
Peter J. Sandiford

Sections Committee

William J. Nemerever, Chairman
Robert Mirsky

Ethics and Grievance Committee

George Shortley

Representative to IFORS

Hugh J. Miser

Representative to the NRC

Robert F. Rinehart

Representative to the AAAS

W. Edward Cushen
Ellis A. Johnson

EDUCATION COMMITTEE

The Education Committee of ORSA plans to sponsor a meeting of Operations Research Faculty in 1966. It is planned to hold a two-day session at the Johns Hopkins University. Topics for discussion include (1) New curriculum and program developments, and (2) Trends in O.R. Manpower. Address: Charles D. Flagle, *Chairman, ORSA Education Committee, The Johns Hopkins Hospital, Baltimore 5, Maryland.*

CURRICULUM DEVELOPMENTS

Reports of curriculum developments should be sent to Prof. Charles D. Flagle, *Chairman ORSA Education Committee, The Johns Hopkins Hospital, Baltimore 5, Maryland.*

U. S. Naval War College, Newport, Rhode Island

Professor Herbert Glazer reports that in 1965–66, the Naval War College Curriculum will contain a study of Military Management. Although specialized to the defense area, the program will resemble the summer courses offered by a number of universities. The lectures will be the responsibility of the Chair of Physical Sciences. The following is a list of topics:

Military Management Study Lecture Series

1. Management in the Military Environment
2. The Influence of the Behavioral Sciences on Management Policies, Practices, Techniques
3. Management and Mathematics

4. Modern Management Techniques
5. Naval Operations Analysis
6. The Elements and Methods of Systems Analysis
7. Technological Considerations in Decision-Making
8. The Digital Computer: (a) Introduction, (b) Applications, (c) Pitfalls
9. War Gaming in the Navy
10. The Computer as an Instrument of Command and Control
11. Naval Studies
12. Material Management Systems
13. A Defense Management View of Computer Software
14. Future ADPS Applications
15. Techniques of Defense Management
16. The Navy Planning System
17. Future Trends in Modern Management
18. Leadership in Military Management

These lecturers will be supplemented by discussions, films, and demonstrations.

Operations Research At North Carolina State University At Raleigh And The University Of North Carolina At Chapel Hill

North Carolina State University at Raleigh and the University of North Carolina at Chapel Hill have offered graduate courses in many areas of Operations Research for a number of years. In addition, numerous OR theses have been directed by staff members of these institutions. Recognizing the need to coordinate and expand these activities, an Operations Research Technical Committee has been appointed, consisting of representatives from ten departments on the two campuses.

After reviewing the OR programs of many well-known institutions and taking account of the indicated needs for OR personnel, the Technical Committee decided that each member of an OR research or development team should contribute strength in at least one basic discipline. Hence it was decided to establish a strong graduate *minor program in Operations Research,* with the major in *any* basic discipline which could contribute to or utilize OR techniques. The OR graduate courses are to be selected from the following general areas:

Control Systems and Reliability (6 courses)
Econometrics and Economic Decision Making (8 courses)
Information and Computer Science (10 courses)
Mathematical Techniques for Optimization (4 courses)
Probability and Statistics (8 courses)

Minimal Course Requirements for Graduate Minors in Operations Research

Master's Degrees. An OR Special Topics course and seminar plus two courses in one of the five OR areas.

Ph.D. Degrees. An OR Special Topics course and seminar plus five other courses, with at least two courses from each of two OR areas.

Prospective students should pay particular attention to the prerequisites for the courses chosen. A student minoring in Operations Research should have a good background in Matrix Algebra, Advanced Calculus and Introductory Probability or be prepared to take such courses early in his graduate program. The Departments of Electrical Engineering and Industrial Engineering have developed one-semester courses to qualify non-engineers to enter certain courses in the areas of Control Systems and Reliability and Information and Computer Science. Such background courses cannot be counted as part of the OR minor program. If a student majors in a discipline which includes one of the OR areas, he would be expected to take courses from this area as a part of the major and select the OR minor courses from other areas. The cohesive elements in the graduate program are a seminar and the OR Special Topics course.

Admission

Prospective graduate students at North Carolina State University at Raleigh or the University of North Carolina at Chapel Hill should contact the Graduate Dean at the selected institution for Application for Admission forms and for a copy of the graduate catalog. Space is provided on the application forms to indicate a desire for an OR minor. The graduate catalog presents the requirements for admission to and the regulations of the Graduate School and a description of departmental programs and course offerings.

Detailed information regarding the Operations Research graduate program can be obtained from the Chairman of the Technical Committee.

Operations Research Technical Committee

Richard L. Anderson, Chairman of the Technical Committee and Professor of Experimental Statistics
John F. Bogdan, Professor of Textiles
Frederick F. Brooks, Jr., Professor and Chairman of Department of Information Science (Chapel Hill)
Arthur R. Eckels, Professor of Electrical Engineering
Cleon Harrell, Associate Professor of Economics
David A. Link, Assistant Professor of Agricultural Engineering
Robert W. Llewellyn, Professor of Industrial Engineering
LeRoy B. Martin, Jr., Assistant Professor of Mathematics
George E. Nicholson, Jr., Professor and Chairman of Department of Statistics (Chapel Hill)
James A. Seagraves, Associate Professor of Agricultural Economics

Associated Faculty

In addition to the members of the Technical Committee, 26 associated faculty members are available to teach OR courses and direct graduate work.

COST-EFFECTIVENESS SECTION

The members of the Cost-Effectiveness Section of ORSA have just elected their initial slate of officers. They are to serve from August 1, 1965 to the Summer of 1966:

John W. Locke, *Chairman*
Herbert K. Weiss, *Vice-Chairman*
Harry P. Hatry, *Secretary*
Joseph W. Noah, *Treasurer*

LOS ANGELES NATIONAL MEETING OF ORSA

The 29th National Meeting of ORSA will be held at the Miramar Hotel in Santa Monica, California during May 18–20, 1966. Expanding Horizons of Operations Research is the theme. DR. JOHN E. WALSH of System Development Corporation is the *Meeting Chairman* and PROFESSOR ALAN J. ROWE of the University of Southern California is *Program Chairman.* This meeting is being held in exceptionally pleasant surroundings (adjoining Pacific Palisades Park overlooking beautiful Santa Monica Bay in smog-free Santa Monica). Paper sessions are being organized by technical sections of ORSA and, perhaps, by some societies in fields related to operations research. Submission of contributed papers is encouraged (from members and nonmembers). January 1, 1966, is the deadline for contributed papers (abstracts of 200 words or less), which are to be sent to DR. JOHN E. WALSH, *System Development Corporation, Santa Monica, California.*

JOINT WESTERN REGIONAL MEETING ORSA/TIMS

The Seventh Joint Western Regional Meeting of the *Operations Research Society of America* and *The Institute of Management Sciences* was held at the Ambassador Hotel, Los Angeles, California, April 29–30, 1965. "Developments for Modern Management" was the topic of the theme address delivered by Dr. RAOUL J. FREEMAN. Other general events included a Panel Discussion, "The Next Ten Years of Operations Research—Management Science," and a Luncheon Address by Dr. MAX PALEVSKY entitled "Tomorrow's Data Processing and Computers: The Expected and the Unexpected." Five general sessions opened the meeting, followed by specialized sessions on Distribution and Inventory, Marketing, Simulation, Cost/Effectiveness, Computers and Management Decisions, Management Systems, Information Economics, Finance, and Invited Student Papers. WILLIAM C. MCDONNEL, Southern California Gas Company, Los Angeles, California, was *Meeting Committee Chairman.*

SOCIETY AUTHORS (CONTINUED)

A listing of Society Authors, Published in the *Spring,* 1965 issue of the BULLETIN, pages **B-98** through **B-106,** was to be updated with additional listings received by the Editor by August 1, 1965. The listing below is that supplement. (As before, article references have not been included.)

ASH, MILTON, *Optical Shutdown in Nuclear Reactors,* Academic Press (in press).

BIEGEL, JOHN E., *Production Control: A Quantitative Approach,* Prentice-Hall 1963, 230 pp.

DEAN, BURTON V., MAURICE W. SASIENI, and SHIV K. GUPTA, *Mathematics for Modern Management,* John Wiley and Sons, Inc., 1963, 442 pp.

DEAN, BURTON V. (Ed.), *Operations Research in Research and Development,* John Wiley and Sons, Inc., 1963, 289 pp.

FREEMAN, RAOUL J. (Ed.), *Developments for Modern Management,* Western Periodical Company, 1965, 314 pp.

FREEMAN, RAOUL J., "Development Evaluation and Specification Modification,"

Chapter 10 in Dean (Ed.), *Operations Research in Research and Development* (see above).

Karayalcin, Ilhami, *New Models for Planning and Allocation*, Technical University of Istanbul, 1960, 80 pp.

Levin, Howard S., J. J. Corliss and I. K. Feinstein, *Analytic Geometry*, Harper & Brothers, 1949, 370 pp.

Levin, Howard S., *Office Work and Automation*, John Wiley and Sons, Inc., 1956, 203 pp.

Ostle, B. and R. G. Tischer, "Statistical Methods in Food Research," Chapter 4 in *Advances in Food Research*, Vol. 5, edited by E. M. Mrak and others, Institute of Radio Engineers, Inc., 1959.

Ostle, B., *Statistics in Research*, (Second Ed.), Iowa State University Press, Ames, Iowa, 1963.

Ostle, B., "Statistical Methods," Chapter 11 in *Reliability Training Text*, edited by F. M. Gryna and others, Institute of Radio Engineers, Inc., 1959.

Pipes, Louis A., *Matrix Methods for Engineering*, Prentice-Hall, Inc., 1963, 427 pp.

Pipes, Louis A., *Applied Mathematics for Engineers and Physicists* (*Book #1*), McGraw-Hill, 1958, 723 pp.

Saaty, Thomas L., *Mathematical Methods of Operations Research*, McGraw-Hill, 1959, 420 pp.

Saaty, Thomas L., *Elements of Queueing Theory*, McGraw-Hill, 1961, 420 pp.

Saaty, Thomas L., *Nonlinear Mathematics*, McGraw-Hill, 1964, 400 pp.

Saaty, Thomas L., *Graphs and Networks*, McGraw-Hill, 1965, 300 pp.

Seal, Hilary L., *Multivariate Statistical Analysis for Biologists*, Methuen, London, and John Wiley and Sons, Inc., New York, 1964, 207 pp.

Sissen, Roger L., *Management Science Selections*, Data Processing Digest, Los Angeles, 1965, 100 pp.

News and Announcements

INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES 1966 CONFERENCE

The Fourth International Conference on O.R. which is being organised in conjunction with the O.R.S.A. will take place at the Massachusetts Institute of Technology, Cambridge, Mass., from August 29th to September 2nd 1966.
The following preliminary programme has been arranged:

Main Sessions

1. Advances in Techniques of Mathematical Programming.
2. Advances in Techniques of Decision Theory.
3. Advances in Techniques of Stochastic Modelling.

Parallel Sessions

A. Theory of Graphs
B. Marketing
C. Transportation
D. Urban Planning
E. Investment Policy Analyses
F. Scheduling Problems
G. Information Processing
H. Simulation
I. Natural Resources
J. Distribution Systems.

Any members wishing to submit papers to any of these sessions should send details as soon as possible to our Programme Committee representative, Dr. K. D. Tochee, *United Steel Companies Ltd., Cybor House, 1–5 Tapton Hall Road, Sheffield 10, England.*

FIRST DANISH CONFERENCE ON OPERATIONS RESEARCH

The First Danish Conference on Operations Research was held at Aarhus Universitet, April 3–4, 1965. For information address: Mr. Erik Johnsen, Secretary, Institute of Economic Research, Copenhagen School of Economics and Business Administration, Julius Thomsens Plads 10, Copenhagen V, Denmark.

OPERATIONAL RESEARCH SOCIETY

The Society's Annual Conference will be held Monday, September 20, 1965 through Wednesday, September 22, 1965. For details: Operational Research Society, 64 Cannon Street, London, E.C. 4.

FRENCH OPERATIONS RESEARCH SOCIETY

Association Francaise d'Informatique et de Recherche Operationnelle (A.F.I.R.O.) will hold an International Symposium on Long Range Planning for Management in Paris, September 20–24, 1965, in the UNESCO Building, under the aegis of the International Computation Centre in Rome. There will be seven half-day sessions at which about thirty papers will be read. In addition, there will be a program of visits to industrial, and research organizations, excursions in and near Paris, and a Ladies' Program. Address: Mr. J. Weinbach, Permanent Secretary, A.F.I.R.O., 7 Rue de la Chaise, Paris 7eme, France.

ARGENTINE OPERATIONS RESEARCH MEETING

Sociedad Argentina de Investigacion Operativa announces "*V Jornadas Argentinas de Investigacion Operativa*" (Operations Research Meetings) to take place in Buenos Aires on November 3–5, 1965. Address Secretary: Ing. Isidoro Marin, Libertad 1235, Buenos Aires.

PROPOSED "OPERATIONS RESEARCH AROUND THE WORLD" MEETINGS

To promote association among operations researchers of many countries, and to directly encourage operations research activities in several countries, the possibility of holding some coordinated meetings is being considered. These meetings would extend around the world and, tentatively, would occur in 1967. Each meeting would be the responsibility of a society in the country where it is held and, ordinarily, would extend Monday through Thursday, with Friday and the weekend for traveling to the next meeting. Specifically, the first meeting would be in Spain, the second in India, and the third in Japan (tentatively). The International TIMS meeting in Mexico could constitute the fourth and final meeting.

Although these meetings are not yet firmly established, their desirability and possibility has been determined by correspondence among the *Operations Research Society of Spain*, the *Operational Research Society of India*, the *Operations Research Society of Japan*, *TIMS*, and *Western Section ORSA*. DR. JOHN E. WALSH, *System Development Corporation, Santa Monica, California* 90406, U. S. A. is the Coordinator for these proposed meetings. Prospective attendees for some or all of these meetings are requested to contact DR. WALSH. The occurrence of these coordinated meetings depends on the anticipated attendance.

WASHINGTON OPERATIONS RESEARCH COUNCIL (WORC)

The Washington Operations Research Council has elected the following officers for the 1965–1966 season:

Program Chairman—BOYD LADD, *Surveys and Research Corporation*
President—JOHN HONIG, *Honeywell Inc.*
Secretary—WINSTON RILEY III, *C.E.I.R., Inc.*
Treasurer—(MRS.) JOANN LANGSTON, *Operations Research, Inc.*

Board Members are Walter L. Deemer, Joseph A. Engel, Robert N. Grosse, David Van Tijn and the retiring president, A. Blumstein. For further information, address the *Chairman, Publicity Committee:* HERBERT HALBRECT, *Halbrect Associates, Inc., 4641 Montgomery Avenue, Bethesda, Maryland.*

SHORTER NOTICES

Travel grants will be made to a number of qualified mathematicians for attendance at the *International Congress of Mathematicians*, to be held in Moscow on

August 14–24, 1966. Applications must be received before November 1, 1965, by the Division of Mathematics, National Academy of Sciences, National Research Council, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

A *Symposium on Economics of Automatic Data Processing* will be held in Rome, October 19–22, 1965, sponsored by the International Computation Centre. Address: *International Computation Centre, 23 Viale della Civilta del Lavoro, P. O. Box 10053, Rome—EUR.*

The International Computation Centre also announces an Advanced Seminar for ADP at Rome, from October 7, 1965 through April 6, 1966. A program of practical training as well as theory has been planned. A. A. M. VEENHUIS is *Director of the Seminar.*

The *Society for General Systems Research* will hold its annual meeting in Berkeley, California, December 27–31, 1965. For further information address MILTON D. RUBIN, *Secretary-Treasurer, Society for General Systems Research, P.O. Box 208, Bedford, Massachusetts 01730.*

Public Automated Systems Service, a non-profit organization to foster the use of automation in government, publishes a new monthly newsletter, *Public Automation*, in cooperation with a number of cooperating societies, such as the American Public Health Association, International City Managers' Association, and the National Institute of Municipal Law Officers. The monthly feature of *Public Automation* is an espository article, describing current practice, with Vol. 1, No. 1, June, 1965, entitled "Operating a City Databank." For information on this organization, write Public Automated Systems Service, 1313 East 60th Street, Chicago, Illinois 60637. Domestic subscription to the service is $15.00 per year.

The American Institute of Planners, 917 Fifteenth Street, N.W., Room 800, Washington, D.C. 20005, publishes the quarterly *AIP Journal* at $8.00 yearly. The special issue for May, 1965, available at $2.50 each, was devoted to *Urban Development Models: New Tools for Planning.*

The *Fall Joint Computer Conference* will be held November 30–December 2, Las Vegas, Nevada. Address MR. ROBERT GRAY, *Secretary, Program Committee, 1965 FJCC, P.O. Box 49, Santa Monica, California 90406.*

The First Eastern Meeting of the Institute of Management Sciences will be held in Rochester, New York, October 13–15, 1965. General Chairman is LAURANCE G. LOCKE, *Eastman Kodak Co., Rochester, New York.*

The Second Conference on State and Local EDP Systems, October 27–29, 1965, has been announced by New York University's Graduate School of Public Administration and Division of General Education, Four Washington Square North, New York City 10003.

The six hundred twenty sixth meeting of the *American Mathematical Society* will be held at the Massachusetts Institute of Technology, Saturday, October 30, 1965.

PERSONAL ITEMS

PROFESSOR WROE ALDERSON of the Wharton School of Finance and Commerce of the University of Pennsylvania died of a heart attack at his home in Maryland on May 31, 1965. PROFESSOR ALDERSON was a *Founding Member* of the Society and had been a *Member* of it continuously until his death. Born in St. Louis in 1898, he worked with the Commerce Department, The Curtis Publishing Company, and, during the war with the OPA, Bureau of Economic Warfare and The Foreign Economic Administration. From 1944 he was marketing counsel to numerous firms, and from 1959 President of Alderson Associates, Philadelphia, and Professor of Marketing at the University of Pennsylvania. He authored *Market Behavior and Executive Action* and *Planning and Problem Solving*, co-authored *Theory in Marketing*, *Marketing Channels for Manufactured Products*, and contributed many other articles and publications in the field of marketing. Professor Alderson was a Member of the Corporation of Haverford College, a Member of the Board of the American Friends Service Committee, and a former President of the American Marketing Association. He resided at 501 Oakley Rd., Haverford, Pennsylvania, and also Unlike Wales, Royal Oak, Maryland, and leaves a wife, the former Elsie Star Wright, and three children, Asia, Maya, and Evan.

ROBERT F. RINEHART, former Society *President*, has been named to the ranking academic position of Senior Professor at the Naval Post Graduate School at Monterey, California. He leaves Case Institute of Technology, Cleveland, Ohio.

MARTIN L. ERNST, former Society *President*, has been named a Vice-President of Arthur D. Little, Inc., Cambridge, Massachusetts.

GEORGE H. SHORTLY, *ORSA President* and former *Editor* of OPERATIONS RESEARCH, has been named Vice President and Chief Scientist, Booz, Allen Applied Research, Inc. and will continue to be based in Washington. JAMES N. DAVIS, formerly Deputy Assistant Secretary of Defense, was named Vice President and Director of the same organization's Washington Operations.

ABRAHAM CHARNES has been named Walter P. Murphy Distinguished Professor at Northwestern Universities Technological Institute, Evanston, Illinois. Professor Charnes is a former President and Founding Member of the Institute of Management Sciences.

DAVID B. HERTZ, ORSA Council Member, Chairman of the Council of the Institute of Management Sciences and Editor of the ORSA Publications in Operations Research series, has been elected a director of McKinsey & Company, Inc., New York.

R. PATRICK CROUCH has been appointed to the position of Manager, Planning and Inventory Control, AP Parts Corporation, Toledo, Ohio.

WILLIAM A. WALLACE has been appointed Assistant Professor in the School of Management, Rensselaer Polytechnic Institute, Troy, New York.

DONALD C. STEWART has been named Assistant to the President, Superior Cable Corporation, Hickory, North Carolina.

Sidney Firstman has joined the Planning Research Corporation, Los Angeles, California.

Robert E. Machol, Professor and Head of the Department of Systems Engineering, University of Illinois, Chicago, and member of the ORSA Publications Committee, has been named also as Lecturer in Charge of Systems Engineering for courses offered by Bolt, Beranek and Newman Inc., Cambridge, Massachusetts.

Gershon Cooper has been appointed a member of the Board of Directors of Dunlap and Associates, Inc., Darien, Connecticut.

Raymond Nelson is now Systems Engineering Manager, Eastern Operations, FMC Corporation.

Mark Kac, Professor of Mathematics and a member of the Rockefeller Institute, has succeeded Gustav A. Hedlund as Chairman of the Division of Mathematics, National Academy of Sciences-National Research Council.

The Institute for Defense Analyses (IDA) has announced the appointment of Bruno W. Augenstein, Research Adviser to the President, Milton U. Clauser, Director Research and Engineering Support Division, and Robert H. Fox, Deputy Director of the same Division.

Research Analysis Corporation (RAC) has added new Members to the Board of Trustees: Finn J. Larsen, vice president of Honeywell Inc.; John Stuart Foster, Jr., Director of the University of California's Radiation Laboratory; Arthur E. Raymond, retired vice president of engineering of Douglas Aircraft Co., James H. Wakelin, Jr., President, Scientific Engineering Institute; and Ambassador Livingston T. Merchant, Executive Director of the World Bank.

The Center for Naval Analyses reports the following have joined its staff: Herbert S. Shank, Melvin D. Miller, Frank Shoup, Merritt E. Ford, Paul Hogroian, James L. Cotton, Carl L. Barton. Frank E. Bothwell, Chief Scientist of CNA, has also been appointed Director of CNA.

Reynold Greenstone is on temporary assignment, Ordnance Research Laboratory, The Pennsylvania State University, while remaining an employee of Operations Research Incorporated. ORI also reports the following have joined the staff of that organization: Albert C. Ballaseyus, Frederick W. Mill, Robert J. Krane, Steven E. Gottlieb, Hugh C. Daubek, Joseph M. Sheehan, Kenneth R. Stewart, Jack E. McCleaf, Jean Edward Smith, John R. Thurber, Sol W. Malasky, Vincent J. Ryba, James I. Strang.

INSTRUCTIONS FOR CONTRIBUTORS TO THE ORSA BULLETIN

The *News and Announcements* section of the Bulletin carries meeting notices of general interest, notices of personal interest, and also miscellaneous items.

The closing deadline for inclusion in the *Spring* Bulletin is January 15th yearly, and for the *Fall* Bulletin, July 15th yearly. (Publication date for the Spring issue is approximately March 15th, and September 25th for the Fall issue.) Notices not received in time for current publication are not used, unless they are of historical interest. Material for the Bulletin should be directed to the *Editor*, Dr. Van Court Hare, Jr., Analytical Associates, Inc., 420 Lexington Ave., New York, N.Y. 10017.

In general, special courses and seminars offered by commercial organizations are not listed, and University short courses are listed only when they are of special interest. Announcements of new products or equipment developments are not listed. Current information reporting the activities of foreign operations research societies is particularly welcome, as are reports of ORSA Section and local meetings, personal announcements *about ORSA members*, and other current information which may be considered noteworthy yet unsuitable for publication in OPERATIONS RESEARCH, the Society's Journal. Reports of University curricula developments should be sent to PROF. CHARLES D. FLAGLE, *Chairman ORSA Education Committee, The Johns Hopkins Hospital, Baltimore 5, Maryland.*

Authors of Invited and Contributed papers to ORSA Meetings will greatly ease the burden of the *Program Chairman* and the *Editor* if they will observe the following three rules of presentation and format:

1. BULLETIN policy is to publish *one paragraph abstracts*, and most multiple paragraph abstracts automatically are edited to conform to this style. Outline form is usually confusing when so edited, so authors are requested to explain the topic at hand in one-paragraph form if this is possible.

2. To allow for ease in correction, styling and type-setting, *double spacing* should be used by authors for *all* copy submitted. Do not underline, use all upper case type, or otherwise attempt to style submitted copy. (For example, names, addresses, organizations, or subject titles should be typed in upper and lower case format with the following exceptions: acronyms—such as ORSA, NATO, PERT, etc.—should be typed in upper case, the titles of books should be underlined, and the titles of articles should appear in quotation marks.

3. Authors are requested to supply their Meeting and Session Chairmen with complete mailing addresses which will be printed in the BULLETIN. (Each meeting usually produces world-wide reprint request for papers. Such requests must be mailed to authors or returned with regrets. Should reprints of an article *not* be available upon request, much correspondence would be saved by noting this fact at the end of each submitted abstract.)

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JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

Volume 60 September 1965 Number 311

Asymptotically Optimal Tests of Composite Hypotheses for Randomized Experiments with Noncontrolled Predictor Variables *Jerzy Neyman and Elizabeth L. Scott*

A Review of "Smoking and Health" .... *K. A. Brownlee*

Demand for Manufacturer's Services for Bakery Products and Fruits and Vegetables .... *William H. Waldorf*

Optimum Stratified Sampling Using Prior Information . *W. A. Ericson*

Stratified Sampling and Distribution-free Confidence Intervals for a Median *Philip J. McCarthy*

Double Sampling for Stratification on Successive Occasions *D. Singh and B. D. Singh*

The Inverted Dirichlet Distribution with Applications *George C. Tiao and Irwin Guttman*

The Estimation of Variance Components in the One-Way Model *Bruce M. Hill*

Sequential Range Tests for Components of Variance . ... *B. K. Ghosh*

Exact Distribution of the Sum of Independent Identically Distributed Discrete Random Variables... .... *Herbert A. David and J. E. Norman, Jr.*

On the Asymptotic Efficiency of the Kolmogorov-Smirnov Test . *Jack Capon*

A Comparison of the Pearson Chi-square and Kolmogorov Goodness-of-Fit Tests With Respect to Validity . ... *Malcolm J. Slakter*

On An Extreme Rank Sum Test with Early Decision. . .. . *D. Chun*

Extended Tables of the Wilcoxon Matched Pair Signed Rank Statistic *Robert L. McCornack*

Tables of Bounds for Distributions with Monotone Hazard Rate *Richard E. Barlow and Albert W. Marshall*

General Theory of Prime-Power Lattice Designs *W. T. Federer and B. L. Raktoe*

Multivariate Acceptance Sampling Procedures for General Specification Ellipsoids.... .... *Melvin F. Shakun*

Quadratic Regression with Inequality Restraints of the Parameters *R. R. Hocking*

Book Reviews

For further information, please contact:
American Statistical Association
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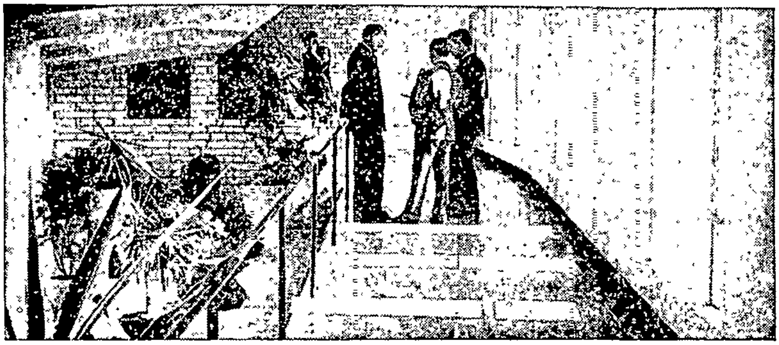
Present areas of strong emphasis include cost effectiveness and resource allocation studies in chemical and biological warfare, ASW, non-military oceanography, space systems such as Nimbus and Polaris, personnel-manpower systems, supersonic transport economics, reliability and performance analysis of meteorological and solar observation satellites for NASA, and work with the Army Institute for Advanced Studies.

Corporate headquarters are in Silver Spring, Maryland (suburban Washington, D. C.). A second office is maintained in Santa Monica, California where an experienced staff is ready to undertake assignments of any magnitude for clients in the Western United States. ORI maintains field groups in residence at the Army War College and Ordnance Research Laboratory.

May we tell you more about ORI's capabilities, and outline our background in your specific problem areas? Please write: Dr. Emory Cook, President

Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland (Suburb of Washington, D. C.). An equal opportunity employer.

OPERATIONS ANALYSTS • SYSTEMS ENGINEERS



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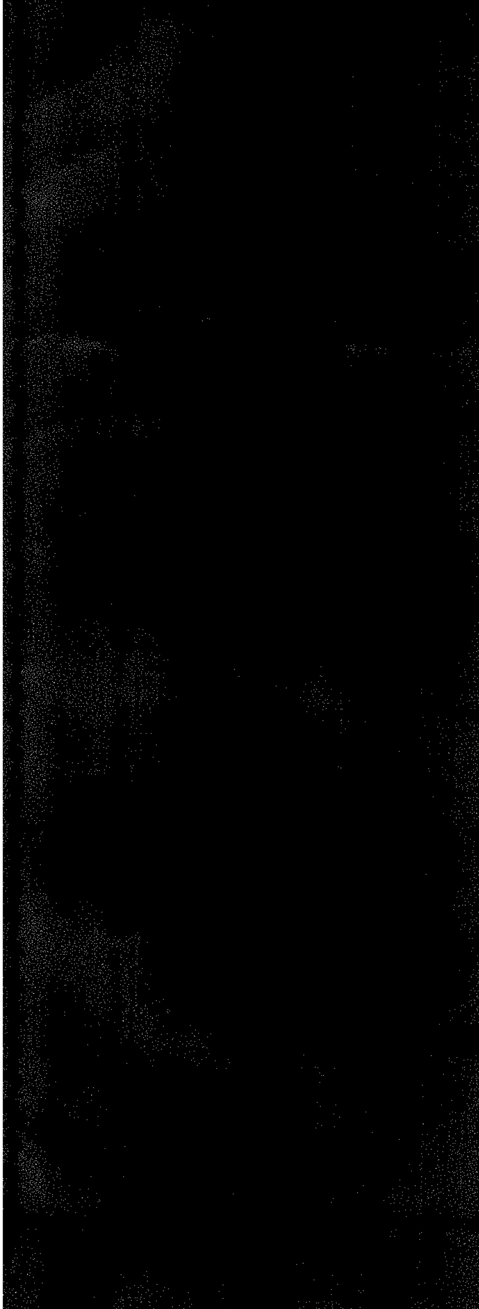

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